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NAVY AIRCRAFT CARRIERS

Cost-Effectiveness of Conventionally and Nuclear-Powered Carriers



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**National Security and
International Affairs Division**

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The Honorable Daniel K. Inouye
Ranking Minority Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable C.W. Bill Young
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The aircraft carrier forms the building block of the Navy's forward deployed peacetime presence, crisis response, and war-fighting forces. The nuclear-powered carrier is the most expensive weapon system in the Nation's arsenal and represents a significant portion of the Navy's shipbuilding and conversion future years defense program. As requested, this report discusses the cost-effectiveness to the Navy of using conventionally and nuclear-powered aircraft carriers. As the Defense Department and the Navy assess design concepts for a new class of carriers, they will evaluate a number of factors, including different propulsion types. This report contains information and analysis that you may find useful in the process of allocating future defense resources.

We are sending copies of this report to the Secretaries of Defense, Navy, Energy, and State and the Director, Office of Management and Budget. Copies will also be made available to others on request.

Please contact me on (202) 512-3504 if you or your staff have any questions concerning this report. Major contributors to this report are listed in appendix VIII.

A handwritten signature in cursive script that reads 'Richard Davis'.

Richard Davis
Director, National Security
Analysis

Executive Summary

Purpose

The Defense Appropriations Act of 1994 Conference Report directed GAO to study the cost-effectiveness of nuclear-powered aircraft carriers. The aircraft carrier forms the building block of the Navy's forward deployed peacetime presence, crisis response, and war-fighting forces. The nuclear-powered aircraft carrier (CVN) is the most expensive weapon system in the Nation's arsenal. Pursuant to the Conference Report, GAO (1) compared the relative effectiveness of conventionally powered and nuclear-powered aircraft carriers in meeting national security requirements, (2) estimated the total life-cycle costs of conventionally powered and nuclear-powered carriers, and (3) identified implications of an all nuclear carrier force on overseas homeporting in Japan and overseas presence in the Pacific region.

Background

Navy policy, doctrine, and practice have been to operate aircraft carriers as the centerpiece of the carrier battle group. The standard carrier battle group includes the carrier and its air wing, six surface combatants, two attack submarines, and one multipurpose fast combat supply ship. As a major element of a carrier battle group, surface combatants provide the primary defensive capabilities for the group. Navy guidance states that one or more surface combatants are necessary at all times to escort and protect the aircraft carrier. Collectively, the battle group's forces provide the combatant commanders with an adequately balanced force to offensively and defensively deal with a range of threats.

Throughout the 1960s and most of the 1970s, the Navy pursued a goal of creating a fleet of nuclear carrier task forces. The centerpiece of these task forces, the nuclear-powered aircraft carrier, would be escorted by nuclear-powered surface combatants and nuclear-powered submarines. In deciding to build nuclear-powered surface combatants, the Navy believed that the greatest benefit would be achieved when all the combatant ships in the task force were nuclear-powered. The Navy ceased building nuclear-powered surface combatants after 1975 because of the high cost. Recently, most of the remaining nuclear-powered surface combatants have been decommissioned early because they were not cost-effective to operate and maintain.

The 1993 Bottom-Up Review prescribed a force of 12 aircraft carriers. The Quadrennial Defense Review of 1997 reaffirmed the need to retain 12 carriers. At the end of fiscal year 1997, the Navy's force consisted of four conventionally powered carriers and eight nuclear-powered carriers. One

of the conventionally powered carriers is homeported in Yokosuka, Japan, and another is in operational reserve status.

The Navy is building two nuclear-powered Nimitz-class carriers, the Harry S. Truman (CVN-75) and the Ronald Reagan (CVN-76), which are scheduled to be delivered in fiscal years 1998 and 2003, respectively. In fiscal year 2001, the Navy will begin to build the last Nimitz-design carrier, CVN-77. These nuclear-powered carriers will replace three of the four conventionally powered carriers now in the force.

The U.S.S. Nimitz (CVN-68) begins a 3-year refueling complex overhaul in fiscal year 1998 at an estimated cost of \$2.1 billion (then-year dollars), followed by the U.S.S. Eisenhower (CVN-69) in fiscal year 2001 at an estimated cost of \$2.3 billion (then-year dollars). Table 1 shows the changes in the Navy's carrier force through fiscal year 2018 based on planned service lives.

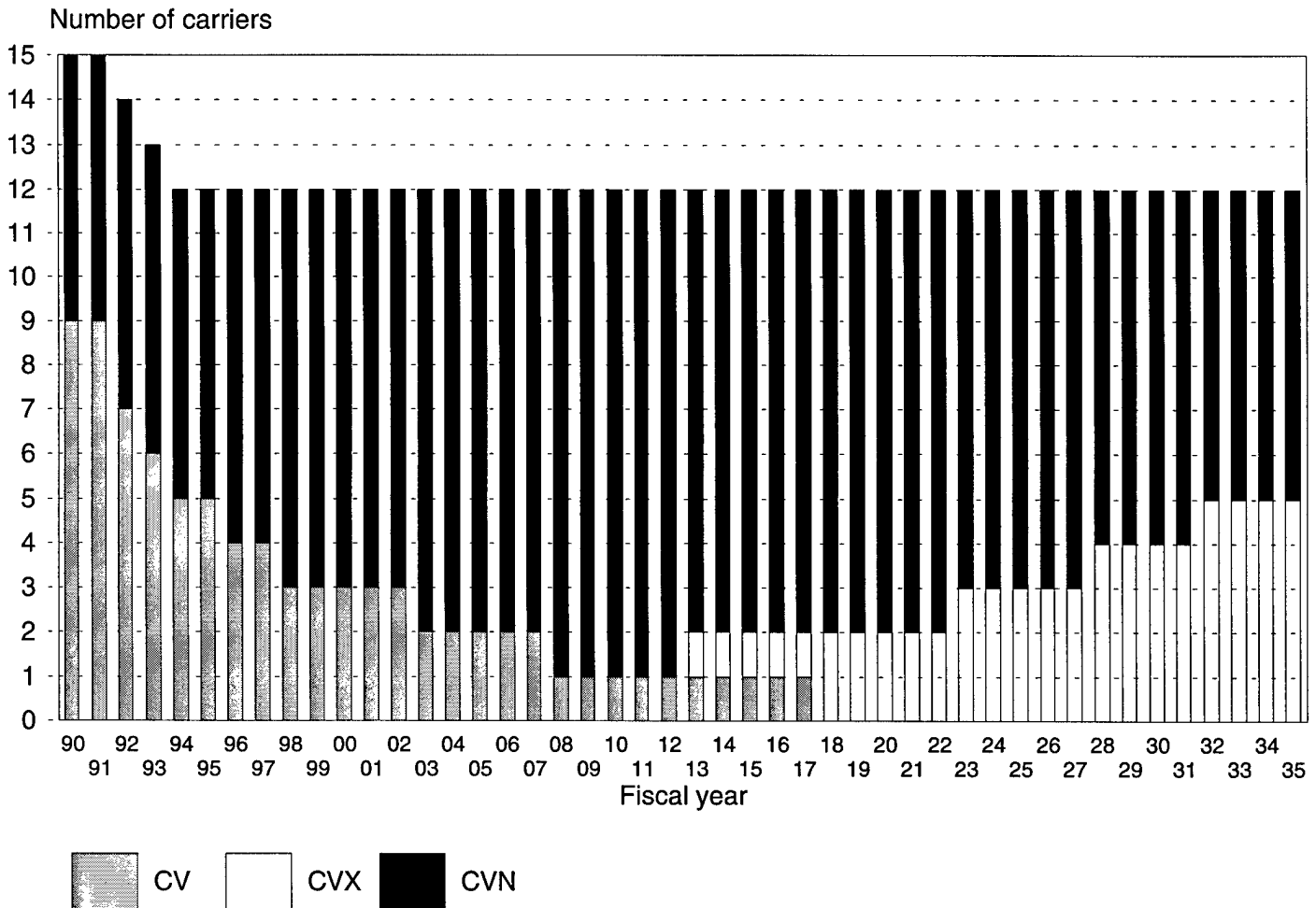
Table 1: Navy's Carrier Force Structure Plan (end of fiscal year)

	1996	1998	2003	2008	2013	2018
CV-Active Conus	2	1	0	0	0	0
CV-Japan	1	1	1	0	0	0
CV-Reserve training	1	1	1	1	1	0
Total conventional	4	3	2	1	1	0
Total nuclear	8	9	10	11	10	10
Planned carrier CVX class	0	0	0	0	1	2
Total	12	12	12	12	12	12

Key: CV=conventionally powered carriers.

The Navy is assessing design concepts for a new class of aircraft carriers, designated the CVX. As a part of this assessment, the Navy will study a number of factors, including various types of propulsion. The formal design process for CVX began in 1996. The project received \$45.7 million in fiscal year 1998 and \$190.2 million is being requested for fiscal year 1999. One of the principal objectives of the CVX project is to reduce life-cycle costs by 20 percent. The Navy wants to begin building the first CVX-78 class carrier in fiscal year 2006 and commission it in 2013. Notwithstanding the decision on the propulsion type for the CVX, a majority of the Navy's carriers will be nuclear-powered for at least the next 30 years (see fig. 1).

Figure 1: Illustrative Carrier Force Mix with CVX Carriers, 1990-2035



Source: GAO analysis of Navy data.

GAO studied the cost-effectiveness of nuclear-powered aircraft carriers, including analyses of total life-cycle costs and the implications of an all nuclear-powered fleet on overseas homeporting. After consulting with the Joint Staff, Office of the Secretary of Defense, and Navy officials, GAO identified three principal measures of effectiveness to evaluate the relative

effectiveness of conventionally and nuclear-powered carriers in meeting national security requirements and objectives: (1) overseas presence, (2) crisis response, and (3) war-fighting. GAO examined the major assumptions and requirements used in developing overseas presence, crisis response, and war-fighting plans and evaluated the recent operational experience of the conventionally and nuclear-powered carrier force. GAO also evaluated several characteristics and capabilities of large, modern conventionally and nuclear-powered carriers. Relying principally on Navy data, GAO examined the historical and projected costs to acquire, operate, support, inactivate, and dispose of conventionally and nuclear-powered carriers such as those now in the force. Unless otherwise noted, GAO used the Kitty Hawk/John F. Kennedy-class and the Nimitz-class aircraft carriers in its conventionally and nuclear-powered carrier cost-effectiveness analysis.

Results in Brief

GAO's analysis shows that conventional and nuclear carriers both have been effective in fulfilling U.S. forward presence, crisis response, and war-fighting requirements and share many characteristics and capabilities. Conventionally and nuclear-powered carriers both have the same standard air wing and train to the same mission requirements. Each type of carrier offers certain advantages. For example, conventionally powered carriers spend less time in extended maintenance, and as a result, they can provide more forward presence coverage. By the same token, nuclear carriers can store larger quantities of aviation fuel and munitions and, as a result, are less dependent upon at-sea replenishment. There was little difference in the operational effectiveness of nuclear and conventional carriers in the Persian Gulf War.

Investment, operating and support, and inactivation and disposal costs are greater for nuclear-powered carriers than conventionally powered carriers. GAO's analysis, based on an analysis of historical and projected costs, shows that life-cycle costs for conventionally powered and nuclear-powered carriers (for a notional 50-year service life) are estimated at \$14.1 billion and \$22.2 billion (in fiscal year 1997 dollars), respectively.

The United States maintains a continuous presence in the Pacific region by homeporting a conventionally powered carrier in Japan. If the U.S. Navy transitions to an all nuclear carrier force, it would need to homeport a nuclear-powered carrier there to maintain the current level of worldwide overseas presence with a 12-carrier force. The homeporting of a nuclear-powered carrier in Japan could face several difficult challenges,

and be a costly undertaking, because of the need for nuclear-capable maintenance and other support facilities, infrastructure improvements, and additional personnel. The United States would need a larger carrier force if it wanted to maintain a similar level of presence in the Pacific region with nuclear-carriers homeported in the United States.

GAO's Analysis

Operational Effectiveness of Conventionally Powered and Nuclear-Powered Carriers

To evaluate the relative effectiveness of conventionally and nuclear-powered aircraft carriers in meeting national security requirements and objectives, GAO identified three principal measures of effectiveness: (1) overseas presence, (2) crisis response, and (3) war-fighting.

Using the Navy's Force Presence Model and data, GAO's analysis shows that, on a relative basis, a force of 12 conventional carriers, when compared to a force of 12 nuclear carriers, can provide a greater level of overseas presence in the European Command, the Central Command, and the Western Pacific¹ or that a force of 11 conventionally powered carriers can provide an equivalent level of forward presence as a force of 12 nuclear-powered carriers. Because a conventionally powered carrier's maintenance requirements are not as stringent and complex as those of a nuclear-powered aircraft carrier, the conventionally powered carrier spends a smaller proportion of its time in maintenance than does the nuclear aircraft carrier and, thus, is more available for deployment and other fleet operations. Unified Commanders consider the quality of presence of the two types of carriers to be the same.

Navy carriers have been tasked to respond to various crises across the full range of military operations, from humanitarian assistance to major theater wars. Nuclear-powered carriers are known for their abilities to sustain long duration high-speed transits. Although both types of carriers can transit to crisis areas at the same top speed, the conventional carriers take somewhat longer to cover long distances than nuclear carriers due to their need to refuel. For example, GAO's analysis of Navy data indicates that in an 18-day voyage from the U.S. West Coast to the Persian Gulf, a distance of about 12,000 nautical miles, steaming at a sustained speed of

¹An all conventionally powered carrier force and an all nuclear-powered carrier force were used to illustrate the relative ability of the two carrier types to fulfill peacetime overseas deployment requirements. This analysis assumes that a carrier is permanently forward deployed in Japan.

28 knots, a conventional carrier would arrive about 6 hours later than a nuclear carrier. On a shorter voyage from the U.S. East Coast to the eastern Mediterranean Sea, a distance of about 4,800 nautical miles, a conventional carrier would arrive about 2 hours later than a nuclear carrier. Neither of these two examples include the time delay caused by refueling the other ships in the battle group, which would have the same refueling requirements, regardless of the carrier's propulsion.

Conventionally powered carriers can be available sooner for large scale crises because it is easier to accelerate or compress their maintenance. Carrier maintenance periods can be shortened by varying degrees, depending on the stage of the maintenance being performed.² The degree a depot maintenance period can be shortened—or surged—depends on when the decision is made to deploy the carrier. For both types of carriers, the decision must be made early if the period is to be substantially shortened. Due to the complexity of its maintenance, a nuclear carrier's maintenance period cannot be surged to the same degree as that of a conventional carrier. In addition, the crews for both carrier types train to the same standards, except for the power-plant crew, and spend comparable time in predeployment training.

GAO found little difference in the operational effectiveness of nuclear and conventional carriers in the Persian Gulf War. Although the Navy had opportunities to place more nuclear carriers in the combat zone, it followed previously planned deployment schedules. As a result, five of the six carriers that participated in the air campaign were conventionally powered. GAO found that the Navy operated and supported all six carriers and their battle groups in essentially the same manner during the conflict. Each battle group was assigned its own dedicated support ships, which enabled frequent replenishment of fuel and ordnance. Conventional carriers replenished aviation fuel about every 2.7 to 3.1 days and the nuclear carrier every 3.3 days—after only a fraction of their fuel and supplies were exhausted. The distance to targets and the number and mix of aircraft aboard each carrier, rather than propulsion type, determined the number of air sorties flown. The average number of sorties flown were nearly identical for both types of carriers when based on the number of aircraft assigned to the respective carriers.

²An employment cycle typically includes three maintenance periods, three predeployment training periods, and three deployments. For the conventionally powered carrier, two of the maintenance periods last 3 months and the other maintenance period lasts 12 months, and for the nuclear-powered carrier, the first two periods last 6 months and the final period lasts 10-1/2 months.

In comparing their characteristics and capabilities, GAO found that the two types of carriers are similar in many respects. For example, both carriers follow the same operational guidance; have the same standard airwing; and, can surge to conduct additional air operations, if necessary. The most noticeable differences are the nuclear carrier's ability to steam almost indefinitely without needing to replenish its propulsion fuel and its larger aircraft fuel and ordnance storage capacity, thereby further reducing dependence on logistics support ships. The larger storage capacity is primarily due to design decisions that have little to do with propulsion type.³ Nuclear carriers still need periodic resupply of aviation fuel, ordnance, and other supplies, and as such, remain dependent on logistics support ships to sustain extended operations at sea. Logistics support ships are an integral part of carrier battle groups and accompany the groups during peacetime deployments, in crisis response, and during wartime. Nuclear carriers also can accelerate faster than conventional carriers, enabling them to respond faster if conditions affecting the recovery of landing aircraft suddenly change, but the Navy could not provide any examples where an aircraft was lost because a conventionally powered carrier could not accelerate in sufficient time.

Life-Cycle Costs for Nuclear-Powered Carriers Are Higher Than Conventionally Powered Carriers

Nuclear-powered carriers cost more than conventionally powered carriers to acquire, operate and support, and inactivate. GAO estimates that over a 50-year life, the costs of a nuclear-powered carrier is about \$8.1 billion, or about 58 percent, more than a conventionally powered carrier (see table 2). Historically, the acquisition cost for a nuclear-powered carrier has been about double that of a conventionally powered carrier. Midlife modernization⁴ for nuclear-powered carriers is estimated to be almost three times as expensive as a conventionally powered carrier—about \$2.4 billion versus \$866 million (in fiscal year 1997 dollars).⁵

³Analyses by the Naval Sea Systems Command and the Center for Naval Analyses show that a Nimitz-class nuclear design with a conventional propulsion system could provide equivalent aviation ordnance and fuel capacities while retaining the same range and speed characteristics of the current Kennedy-class conventional carrier.

⁴The midlife modernization represents the service life extension program for conventional carriers and the nuclear refueling complex overhaul for nuclear carriers. Both investments accomplish the common objectives of extending the operating life of the ship.

⁵The initial nuclear fuel load and its installation are included in the acquisition cost category. The midlife modernization cost category includes removal of the initial fuel load. It also includes the cost of the replacement fuel load and its installation.

Table 2: Life-Cycle Costs for a Conventionally Powered Carrier and a Nuclear-Powered Carrier (based on a 50-year service life)

Fiscal year 1997 dollars in billions		
Cost category	Conventionally powered carrier	Nuclear-powered carrier
Investment cost^a	\$2.916	\$6.441
Ship acquisition cost	2.050	4.059
Midlife modernization cost	0.866	2.382
Operating and support cost	11.125	14.882
Direct operating and support cost	10.436	11.677
Indirect operating and support cost	0.688	3.205
Inactivation/disposal cost	0.053	0.899
Inactivation/disposal cost	0.053	0.887
Spent nuclear fuel storage cost	n/a	0.013
Total life-cycle cost	\$14.094	\$22.222

Note: Numbers may not add due to rounding.

^aCVN investment cost includes all nuclear fuel cost; CV fuel is included in operations and support activities.

Source: GAO's analysis.

GAO estimates that nuclear-powered carriers have cost about 34 percent more than conventionally powered carriers to operate and support because personnel and maintenance costs are higher and nuclear-powered carriers require unique support organizations and activities. Personnel costs for nuclear carriers are greater because more personnel are required for a nuclear-powered carrier, nuclear-qualified personnel receive greater total compensation, and they are required to complete additional training. For example, a nuclear-powered carrier needs about 130 more personnel in its engineering and reactor departments than are needed in the conventionally powered carrier's engineering department. Also, each year, nuclear-qualified officers receive up to \$12,000 and nuclear qualified enlisted personnel receive about \$1,800 more than personnel do in nonnuclear jobs.

Nuclear-powered carriers are also more costly to maintain because the scope of work is larger and considerably more labor hours are required. Because of the complex procedures required to maintain nuclear power plants, shipyard workers must be specifically trained to maintain nuclear carriers. Additionally, the materials used in nuclear carriers must meet exacting standards and the shipyards must have the facilities needed for the specialized work. Also, these projects cost more because of the unique

industrial base, specialized nuclear suppliers, and the Naval Nuclear Propulsion Program's exacting and stringent environmental, health, and safety standards. Shipbuilders must follow "non-deviation" plans (i.e., no deviation from the approved plans without government approval). An unavoidably high cost overhead structure (engineering, quality assurance, and production control) and costly production work are required in the naval nuclear propulsion industry. Based on the Navy's maintenance plans, GAO estimates that over a 50-year life, nearly 40 percent more labor hours are needed to maintain a nuclear-powered carrier than are required to maintain a conventionally powered carrier.

The Navy estimates that it will cost between \$819 million and \$955 million to inactivate and dispose of the first Nimitz-class nuclear-powered carrier. This is almost 20 times more costly than the \$52.6 million that is estimated it will cost to inactivate and dispose of a conventionally powered carrier. Most of the costs can be attributed to removing contaminated nuclear equipment and material, including the highly radioactive spent fuel.

Implications of an All Nuclear Carrier Force on Homeporting a Carrier in Japan and Overseas Presence in the Pacific Region

Homeporting Navy ships overseas enables the United States to maintain a high level of presence with fewer ships because the need for a rotation base to keep forces deployed is smaller. A conventionally powered carrier has been permanently forward deployed in Japan since 1973. Japan currently pays a substantial share of the costs for the permanently forward deployed carrier, including all yen-based labor, berthing and maintenance facilities improvements, and other support costs such as housing.

The last two conventionally powered carriers, including the carrier now homeported in Japan, will reach the end of their service lives in the 2008 to 2018 period. The Navy will have to decide if it wishes to change how it maintains forward presence in the Pacific region. That is, the Navy will have to decide whether to continue the current approach to presence in the region and design and acquire a conventionally powered replacement carrier to homeport in Japan. Alternately, if the Navy wished to provide the same level of presence in the region with nuclear-powered carriers, it would need to (1) establish a nuclear-capable maintenance facility and related infrastructure in Japan to accommodate the nuclear-powered carrier to be homeported there or (2) expand the force to include the additional nuclear-powered carriers that would be necessary, but with ships deployed from the United States.

While it would be several years before the carrier force would undergo a complete transition to nuclear propulsion, it would also take several years to implement any of the strategies that will allow the United States to maintain a long-term continuous naval carrier presence in the Pacific region.

Conclusions

The Navy is assessing design concepts for a new class of aircraft carriers. As part of this assessment, it will evaluate a number of factors, including different propulsion types. GAO's analysis of measures of effectiveness (forward presence, crisis response, and war-fighting) shows that conventionally and nuclear-powered carriers both have effectively met the Nation's national security requirements. The analysis also shows that conventionally powered carriers have lower total life-cycle costs. This report also discusses the implications of a changing carrier force structure on providing overseas presence for the Pacific region.

Agency Comments

The Departments of Defense (DOD), Energy, and State provided comments on a draft of this report. DOD's comments (see app. VII) and GAO's detailed evaluation are included in the report where appropriate.

Overall, DOD partially concurred with the report. Specifically, DOD concurred there is a life-cycle cost premium associated with nuclear power. However, DOD believed GAO's estimate of that premium was overstated by several billion dollars because of what DOD believed are analytic inconsistencies in GAO's analysis. DOD also believed the draft report did not adequately address operational effectiveness features provided by nuclear power.

DOD did not agree with GAO's approach of making cost-per-ton comparisons between the two types of carriers currently in the force, believing the conventionally powered carriers reflect 40-year old technologies. DOD believed a more appropriate cost comparison would include pricing conventionally and nuclear-powered platforms of equivalent capabilities. According to DOD, any analysis of platform effectiveness should include mission, threat, and capabilities desired over the life of the ship. Further, it stated the draft report did not adequately address future requirements but relied on historical data and did not account for platform characteristics unrelated to propulsion type. That is, many of the differences may be explained by platform size, age, and onboard systems than by the type of propulsion.

Congress asked GAO to examine the cost-effectiveness of conventionally and nuclear-powered aircraft carrier propulsion. Such an analysis seeks to find the least costly alternative for achieving a given requirement. In this context, GAO used as the requirement DOD's national military strategy, which is intended to respond to threats against U.S. interests. That strategy encompasses overseas peacetime presence, crises response, and war-fighting capabilities. GAO used those objectives as the baseline of its analysis and selected several measures to compare the effectiveness of conventionally and nuclear-powered carriers. Those measures were discussed with numerous DOD, Joint Staff, and Navy officials at the outset. Those measures reflect the relative capabilities of each propulsion type, including the nuclear-powered carrier's greater aviation fuel and munitions capacity and unlimited range. Notwithstanding the enhanced capabilities of nuclear propulsion, GAO found that both types of carriers share many of the same characteristics and capabilities, that they are employed interchangeably, and that each carrier type possesses certain advantages. GAO also found that both types of carriers have demonstrated that each can meet the requirements of the national military strategy. GAO's analysis shows that conventionally powered carriers can meet that strategy at a significantly lower life-cycle cost.

The primary reason that GAO's analysis shows a higher premium for life-cycle costs of a nuclear-powered carrier is because different methodologies were used. The GAO methodology compared the investment, operating and support, and inactivation/disposal costs of operational carriers. This approach allowed GAO to use historical costs to the extent possible. GAO also used a cost-per-ton approach to develop its acquisition cost estimate. This approach is an accepted method for estimating procurement costs and has been used by the Navy.

The GAO methodology showed that the life-cycle cost premium associated with nuclear propulsion was about \$8 billion per carrier over a 50-year life versus about \$4 billion using the Navy's approach. GAO's and the Navy's estimated life-cycle costs for a nuclear-powered carrier were very similar even though different methodologies were used. However, the life-cycle cost of a conventionally powered carrier using the two methodologies varies significantly—\$14 billion versus \$19 billion. Several factors account for the variance. For example, a different universe of ships was used to determine the estimated cost for a Service Life Extension Program. In estimating procurement costs, the Navy used actual labor hours for the U.S.S. John F. Kennedy (CV-67), adjusted to reflect current labor, overhead, and material rates for a nuclear shipbuilding facility, Newport

News Shipbuilding. Operating and support costs varied, in part, because DOD used fully burdened fuel delivery costs and a different methodology for estimating personnel costs.

GAO believes its methodology of reviewing a historical perspective covering a wide range of peacetime presence, crises response, and war-fighting scenarios that both types of carriers faced during the past 20 years is sound. A full discussion of GAO's methodology can be found in appendix I. GAO continues to believe that this assessment will be helpful to the Navy as it assesses design concepts for a new class of aircraft carriers.

The Energy Department concurred with DOD's comments addressing estimates of costs associated with nuclear reactor plant support activities and storage of naval spent fuel. These comments and GAO's evaluation of them are discussed in appendix VII. The State Department noted that the entry of nuclear-powered vessels into Japanese ports remains sensitive in Japan and there would have to be careful consultations with the government of Japan should the U.S. government wish to homeport a nuclear-powered carrier in Japan.

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Abbreviations

AOE	fast combat support ship
CLF	Combat Logistics Force
CNA	Center for Naval Analyses
COH	complex overhaul
CV	conventionally powered aircraft carrier
CVBG	notional conventional battle group
CVN	nuclear-powered aircraft carrier
CVNBG	notional conventional and nuclear battle group
DFM	diesel fuel marine
DOD	Department of Defense
DOE	Department of Energy
DPIA	Docking Phased Incremental Availability
DSRA	Drydocking Selected Restricted Availability
EOC	Engineered Operating Cycle
FASAB	Federal Accounting Standards Advisory Board
GAO	General Accounting Office
IMP	Incremental Maintenance Program
JFACC	joint force air component commander
JP-5	jet fuel (Navy aircraft fuel)
NAVSEA	Naval Sea Systems Command
nm	nautical mile
NTU	New Threat Upgrade
MSC	Military Sealift Command
OPNAV	Office of the Chief of Naval Operations
OPTEMPO	operating tempo
PERA	Planning, Engraving, Repairs, and Alterations
PERSTEMPO	Personnel Tempo of Operations
PIA	Phased Incremental Availability
QDR	Quadrennial Defense Review
RCOH	Refueling Complex Overhaul
SNF	spent nuclear fuel
SRA	Selected Restricted Availability
SLEP	Service Life Extension Program
VAMOSC	Visibility and Management of Operating and Support Cost

Introduction

Since World War II, the carrier battle group has been a key political and military component in achieving the goals of presence, combining robust crisis response capability with the firepower needed to protect U.S. interests should a conflict erupt. These capabilities are known and respected throughout the world, thereby reinforcing deterrence. The aircraft carrier forms the building block of the Navy's forces. The nuclear-powered aircraft carrier (CVN) is the most expensive weapon system in the Nation's arsenal.

The Defense Appropriations Act of 1994 Conference Report directed us to study the cost-effectiveness of nuclear-powered aircraft carriers. Accordingly, we (1) compared the relative effectiveness of conventionally powered and nuclear-powered aircraft carriers in meeting national security requirements and (2) estimated the total life-cycle costs of conventionally powered and nuclear-powered carriers. We also examined the implications of an all nuclear carrier force on overseas homeporting in Japan. A conventionally powered carrier is permanently homeported there now and operates in the Western Pacific, but it will eventually be replaced with a nuclear-powered carrier if the trend toward an all nuclear carrier force continues.

Building Blocks of U.S. Security Strategy and the Aircraft Carrier

The National Military Strategy states that the military forces must perform three sets of tasks to achieve the military objectives of promoting stability and thwarting aggression — (1) peacetime engagement, (2) deterrence and conflict prevention, and (3) fighting and winning the Nation's wars. Accomplishing the specific tasks of the strategy is facilitated by the two complementary strategic concepts of overseas presence and power projection. U.S. forces deployed abroad protect and advance U.S. interests and perform a wide range of functions that contribute to U.S. security.

The aircraft carrier battle group, with the aircraft carrier as the centerpiece, is the focal point for the Navy's operational strategy, *Forward. . . From the Sea*. The strategy underscores the premise that the most important role of naval forces in situations short of war is to be engaged in forward areas, with the objectives of preventing conflicts and controlling crises. The carrier battle group's forward presence demonstrates the Nation's commitment to allies and friends, underwrites regional stability, gains U.S. familiarity with overseas operating environments, promotes combined training among forces of friendly countries, and provides timely initial response capabilities. U.S. naval forces, designed to fight and win wars, must be able to respond quickly

and successfully to support U.S. theater commanders. Forces that are deployed for routine exercises and activities undergirding forward presence are also the forces most likely to be called upon to respond rapidly to an emerging crisis.

The battle group, along with its Combat Logistics Force ships, carries a full range of supplies needed for combat, including fuel and ammunition, which will sustain the battle group for about 30 days, depending on the tempo of operations, enough food to feed the force for 45 days, and sufficient spare parts and other consumables to last for more than 60 days. Moreover, forward-deployed naval forces can draw on an established worldwide logistics pipeline, including Combat Logistics Force ships plus over 22 strategically-located worldwide fuel storage sites, prepositioned munitions, fuel, and other supplies. This logistics force posture gives the U.S. Navy the ability to remain on-station as long as required.

Bottom-Up Review Establishes Carrier Force Size

The Bottom-Up Review was a 1993 evaluation of the Nation's defense strategy, force structure, and modernization and was done in response to the end of the Cold War and the dissolution of the former Soviet Union. The review concluded that the peacetime presence provided by the Navy's aircraft carriers was so important that even though a force of 8 to 10 aircraft carriers could meet the military's war-fighting requirements, the Navy needed 12 carriers (11 active plus 1 reserve/training carrier) to provide sufficient levels of presence in the three principal overseas theaters (the Western Pacific, the Mediterranean Sea, and the North Arabian Sea/Indian Ocean).

Quadrennial Defense Review Reaffirms Carrier Force Size

The Quadrennial Defense Review (QDR), required by the National Defense Authorization Act for Fiscal Year 1997, was designed by the Department of Defense (DOD) to be a fundamental and comprehensive examination of U.S. defense needs from 1997 to 2015: potential threats, strategy, force structure, readiness posture, military modernization programs, defense infrastructure, and other elements of the defense program. The QDR has determined that a total force structure of 12 carriers will allow the United States to sustain carrier battle group deployments at a level that helps shape the international security environment in support of the Nation's security strategy and commitments.

To ensure that DOD continued to provide the right levels and types of overseas presence to meet the objectives stated in its strategy, DOD

undertook a detailed examination of its overseas presence objectives and posture in all regions. This study, conducted by the Office of the Secretary of Defense and the Joint Staff, built on the pre-QDR work done by the Joint Staff and involved all relevant participants, including the services and the regional Commanders in Chief. The analysis formed the basis DOD considered in making its decisions on the appropriate levels of presence in key regions throughout the world.

The demands associated with maintaining an overseas presence play a significant role in determining the size of the carrier force. To illuminate the implications of overseas presence demands an additional analysis was done by the QDR to examine the impact of possible naval force structure options. Using the Navy's Force Presence Model, a range of aircraft carrier force structures were analyzed and compared by the QDR to the forward presence levels then provided in the U.S. European Command, U.S. Central Command, and U.S. Pacific Command areas of responsibility. The analysis concluded that a force of 11 active aircraft carriers plus one operational Reserve/training carrier was necessary to satisfy current policy for forward deployed carriers and accommodate real world scheduling constraints.

General Characteristics of the Modern Conventionally and Nuclear-Powered Aircraft Carriers

Except for their power plants, the conventionally and nuclear-powered aircraft carriers operating in the fleet are very similar in size, form, and function and embark the same standard air wing. As table 1.1 shows, the Kennedy-class conventional carriers and the Nimitz-class nuclear carriers share many common attributes.

Table 1.1: General Characteristics of Modern, Large Deck Conventionally and Nuclear-Powered Carriers

	U.S.S. John F. Kennedy (CV-67)	U.S.S. Nimitz (CVN-68)
Displacement (full load)	82,000 tons	95,000 tons ^a
Ship dimensions		
Length (overall)	1,051 ft.	1,092 ft.
Length (waterline)	990 ft.	1,040 ft.
Beam (waterline)	126 ft.	134 ft.
Beam (flight deck)	268 ft.	251 ft.
Propulsion	8 boilers/4 shafts	2 reactors/4 shafts
Shaft horse power (total)	280,000	280,000
Speed	30+ knots	30+ knots
Aircraft handling		
Maximum density of aircraft ^b	130	130
Catapults	4	4
Elevators	4	4
Crew		
Ship's company ^c	3,213	3,389
Air wing	2,480	2,480
Range (unrefueled)	^d	1.5 million miles
Fuel capacity (in gallons)		
Aviation fuel (JP-5) ^e	1.8 million	3.5 million
Ship fuel (DFM)	2.4 million	N/A
Ordnance (cubic feet) ^f	76-80%	94-100%

^aThe full load displacements of the later ships of the Nimitz-class have increased to about 99,000 tons.

^bA carrier's total aircraft capacity is called its maximum density. The F/A-18 equivalent is the unit of measure for calculating maximum density. The U.S.S. Carl Vinson (CVN-70) has a maximum density of 127. (See ch. 2 for more information.)

^cNumber of officers and sailors needed to operate the ship.

^dA conventional carrier's cruising range varies with its speed. For example, maintaining a 30-percent fuel reserve, it can sail from San Francisco to Hong Kong at 14 knots. At 28 knots, it can sail from Singapore, across the Indian Ocean, to Bahrain in the Arabian Gulf without refueling while maintaining the same reserve.

^eAviation fuel (JP-5) can be substituted for ship fuel (diesel fuel marine (DFM), also known as F-76) in surface ships.

^fMeasured as a percentage of the baseline, which includes the first three Nimitz-class carriers (CVN-68-70); later Nimitz-class carriers have enhanced magazine protection that reduces magazine volume.

Aircraft Carriers Operate as Part of Battle Groups

To provide a balanced force to deal with a range of threats, the Navy employs aircraft carriers as part of a combat formation of ships—a carrier battle group—of which, it considers the aircraft carrier to be the focal point. The collective capabilities of the battle group's ships allow the group to carry out a variety of tasks ranging from operating in support of peacetime presence requirements to seizing and maintaining control of designated airspace and maritime areas and projecting power ashore against a variety of strategic, operational, and tactical targets as discussed in the Policy for Carrier Battle Groups.^{1,2} According to the policy, a battle group can operate in environments that range from peacetime to a “non-permissive environment characterized by multiple threats.”

The policy also established a “standard carrier battle group” that consists of

- one nuclear- or conventionally powered aircraft carrier;³
- one carrier air wing;⁴
- six surface combatants, of which at least
 - three are cruisers or destroyers with Aegis weapons systems,
 - four ships are equipped with Vertical Launching Systems that can fire Tomahawk cruise missiles, and
 - ten antisubmarine warfare helicopters are collectively embarked;
- two attack submarines, one of which is equipped with a Vertical Launch System; and,
- one multipurpose fast combat support ship.

The policy further states that a battle group's composition can vary, depending on the mission needs. Figure 1.1, for example, shows ships of the U.S.S. George Washington battle group as they transit the Suez Canal. (President Clinton ordered elements of the battle group to the Arabian

¹Office of the Chief of Naval Operations, OPNAV Instruction 3501.316, Subject: Policy for Carrier Battle Groups, dated February 17, 1995.

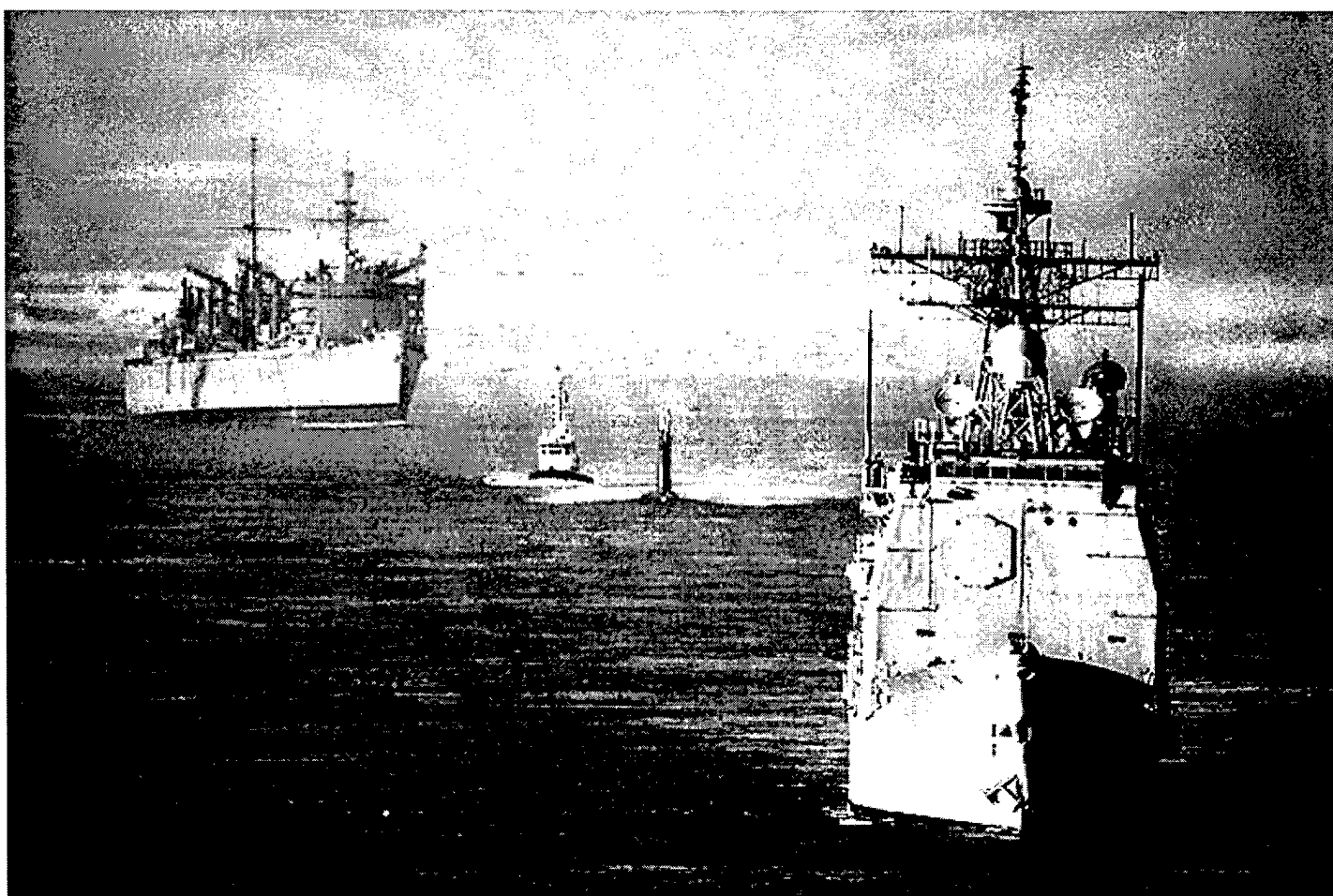
²The specific tasks discussed in the policy are surveillance/intelligence, command and control, air superiority, maritime superiority, power projection, theater ballistic missile defense, operations in support of the peacetime presence mission, amphibious force operations, insertion and withdrawal of land-based forces into uncertain and hostile environments, special operations, combat search and rescue, mine warfare, and sustainment.

³The policy does not differentiate between nuclear and conventional aircraft carriers in its discussion of a carrier battle group's tasks.

⁴The same standard air wing is assigned to both conventionally and nuclear-powered carriers. That wing consists of a mix of 74 fighter, attack, electronic countermeasure, antisubmarine, search-rescue, and surveillance aircraft. (See table 2.5 for a complete list.)

Gulf to support U.N. efforts to compel Iraq's compliance with U.N. resolutions.)

Figure 1.1: Elements of the U.S.S. George Washington (CVN-73) Carrier Battle Group Transit the Suez Canal Toward the Persian Gulf



Note: Pictured are the cruiser U.S.S. Normandy (CG-60) (front), the submarine U.S.S. Annapolis (SSN 760), and the fast combat support ship U.S.S. Seattle (AOE-3) (rear); not pictured, but making the transit, are the U.S.S. George Washington (CVN-73) and the U.S.S. Carney (DDG-64). Members of the George Washington battle group remaining in the Mediterranean Sea include the nuclear-powered cruiser U.S.S. South Carolina (CGN-37), U.S.S. John Rodgers (DD-983), U.S.S. Boone (FFG-28), U.S.S. Underwood (FFG-36), and U.S.S. Toledo (SSN-769).

Source: Navy photo.

The ships perform various roles within the battle group. The aircraft carrier, with its embarked air wing, is the group's principal means of conducting offensive operations against enemy targets. The air wing's aircraft also help defend the battle group against air, surface, and submarine threats. The surface combatants, with their installed missile systems, guns, and torpedoes, defend the aircraft carrier and the rest of the battle group against air, surface, and submarine attack. With their Tomahawk missile systems, surface combatants can also strike enemy targets ashore. Their embarked antisubmarine helicopters also help defend the battle group against submarine and surface threats. The submarines provide protection, surveillance, and intelligence support to the battle group, and their torpedoes and Harpoon missiles contribute to the battle group's defense against enemy submarines and surface threats. As with the surface combatants, the submarines' Tomahawk missile systems allows them to strike targets ashore.

The multipurpose fast combat support ship (AOE) is the only noncombatant ship in the battle group. Its role is the underway replenishment of the ships in the group.⁵ As the battle group's station ship, it resupplies ships with fuel (both JP-5 for the aircraft and DFM for the ships), other petroleum products, ammunition, provisions, and other supplies. This replenishment allows the ships to remain at sea for prolonged periods since they do not have to return to port to be resupplied. The AOE classes of ships can easily cruise for sustained periods at battle group speeds, replenishing and rearming the entire battle force. The ship has the armament to operate as an integral part of the battle group.

The Aircraft Carrier's Employment Cycle

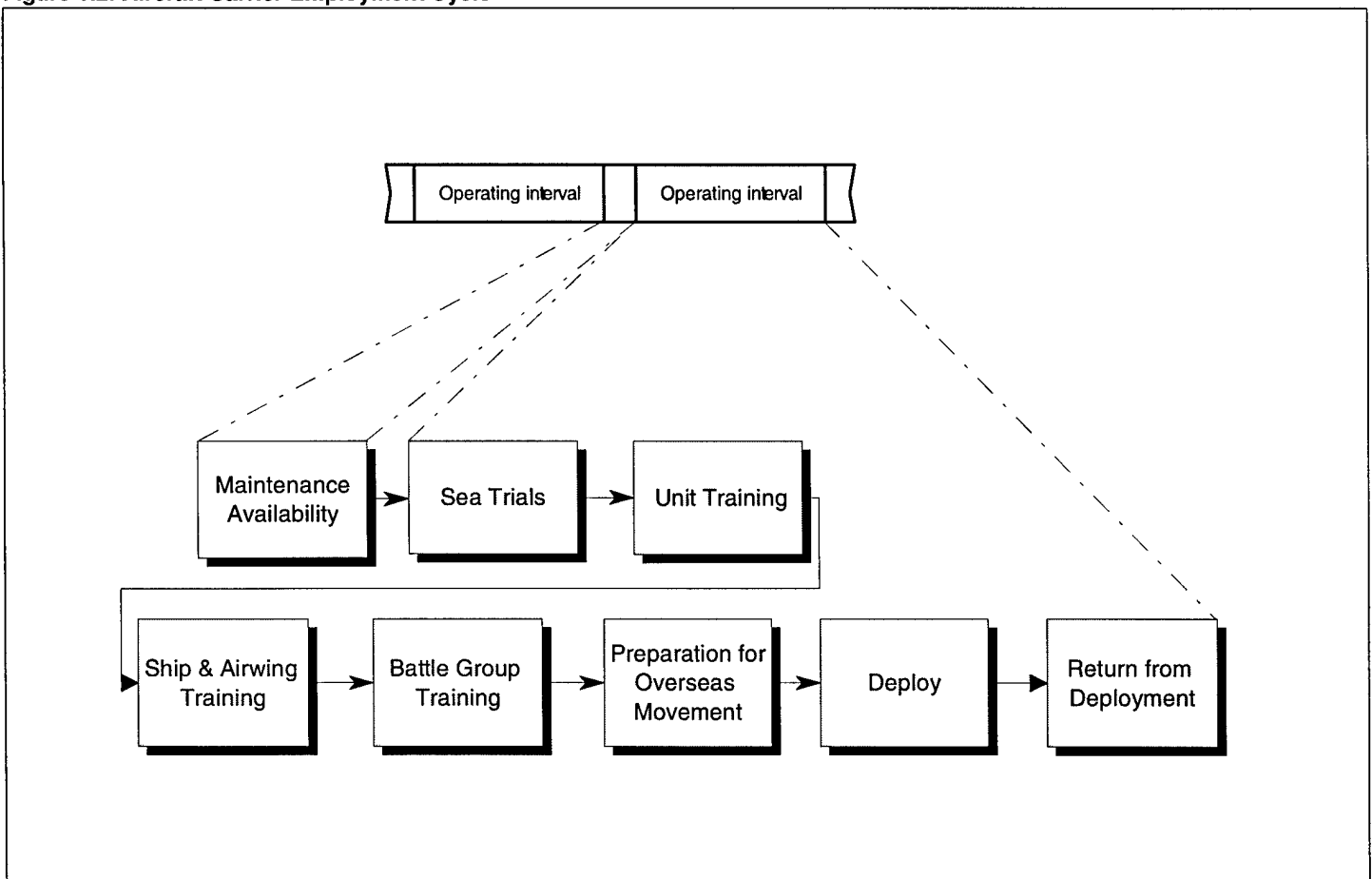
The employment operations of both types of carriers follow a typical cycle comprised of depot-level maintenance periods and intervals during which a carrier prepares for and deploys to overseas theaters. As shown in figure 1.2, the cycle normally begins with a depot-level maintenance period. When the maintenance is completed, the carrier begins interdeployment training, which includes training with the air wing.⁶ With the training's successful completion, the aircraft carrier and its air wing, as part of a battle group, are ready to deploy. Upon returning from an

⁵When an AOE is not available, a combination of ships can be used to carry out its role. These include oilers (AO or T-AO) and ammunition ships (AE and T-AE). However, these other types of ships do not carry the range of products that an AOE carries and, since their top speeds are about 20 knots, they do not have the speed to keep up with the other ships in the battle group at all times.

⁶According to a Naval Air Force, Atlantic Fleet official, the carrier becomes a "surge" carrier when it successfully completes "ship and air wing" training.

overseas deployment, the carrier enters a short stand-down period during which it may be retained in a surge readiness status—a nondeployed carrier that would be tasked to respond to an emerging overseas crisis. After the stand-down, it begins a maintenance period—starting a new cycle.

Figure 1.2: Aircraft Carrier Employment Cycle



Source: Our analysis of Navy data.

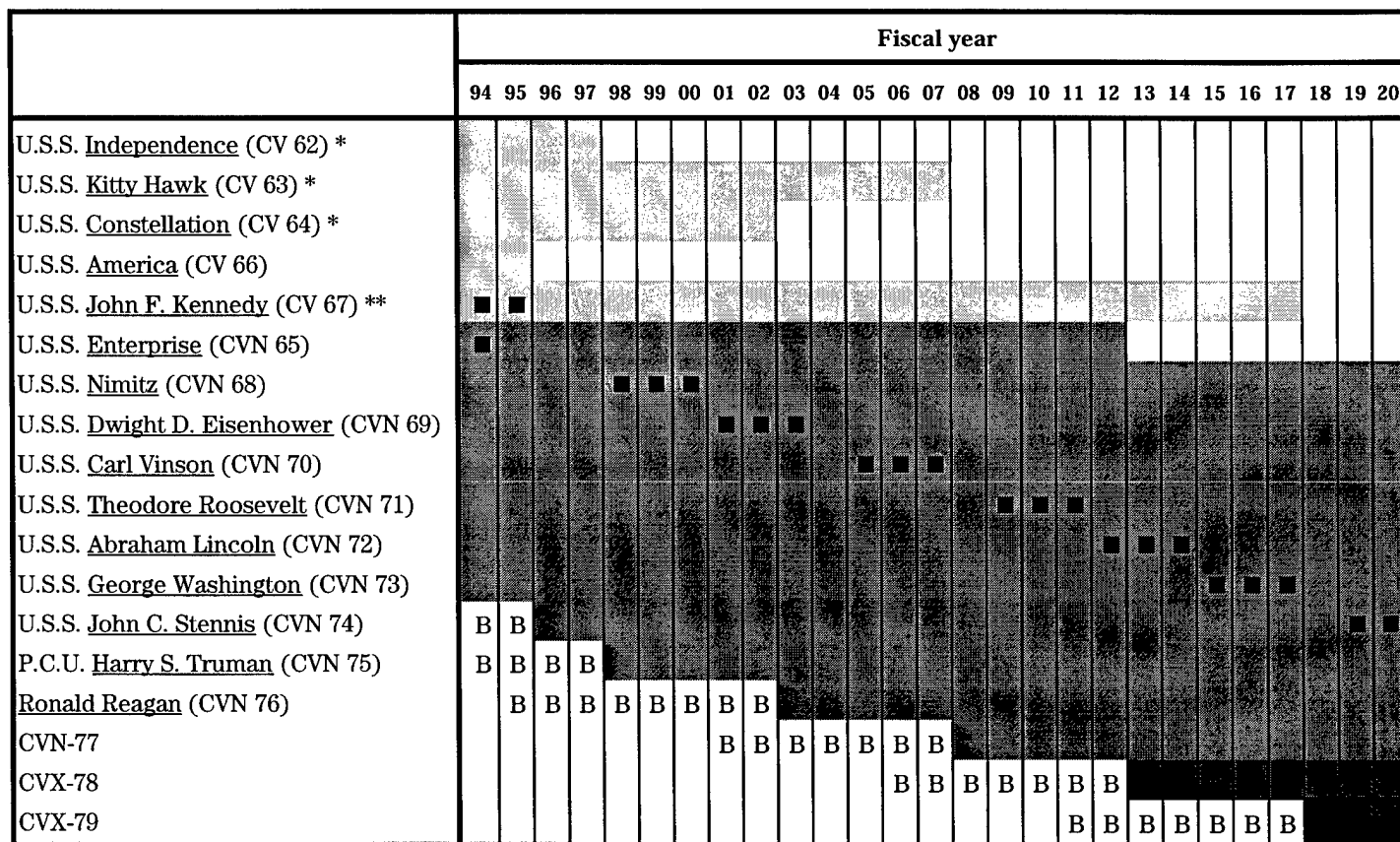
The length of a carrier's employment cycle, sometimes called its maintenance cycle, depends on the carrier's propulsion type and the maintenance strategy it uses. Each cycle typically includes three

depot-level (i.e., shipyard) maintenance periods and three deployments. For the conventionally powered carrier, two of the maintenance periods last 3 months and the other maintenance period lasts 12 months; and, for the nuclear-powered carrier, the first two periods last 6 months and the final period lasts 10-1/2 months. For both carrier types, an 18-month operating interval, including the 6-month deployment, separates the maintenance periods.

Aircraft Carrier Force Structure and Acquisition Plan

The number of conventionally powered aircraft carriers in the force is diminishing. At the end of fiscal year 1997, the Navy's force included four conventionally powered carriers and eight nuclear-powered carriers. One of the conventionally powered carriers is homeported in Yokosuka, Japan, and another, the U.S.S. John F. Kennedy (CV-67), is in the Reserve Fleet. Figure 1.3 shows the Navy's projected carrier force through fiscal year 2020, including its refueling complex overhaul (RCOH) schedule. (See app. VI for a complete list of hull numbers, names, commissioning, and decommissioning dates.)

Figure 1.3: Aircraft Carrier Force Structure for Fiscal Years 1994-2020



Key:

* CV with a midlife modernization

B New carrier building period

CVX class

** Operational reserve carrier

Conventionally powered carriers

Midlife modernization period

Nuclear-powered carriers

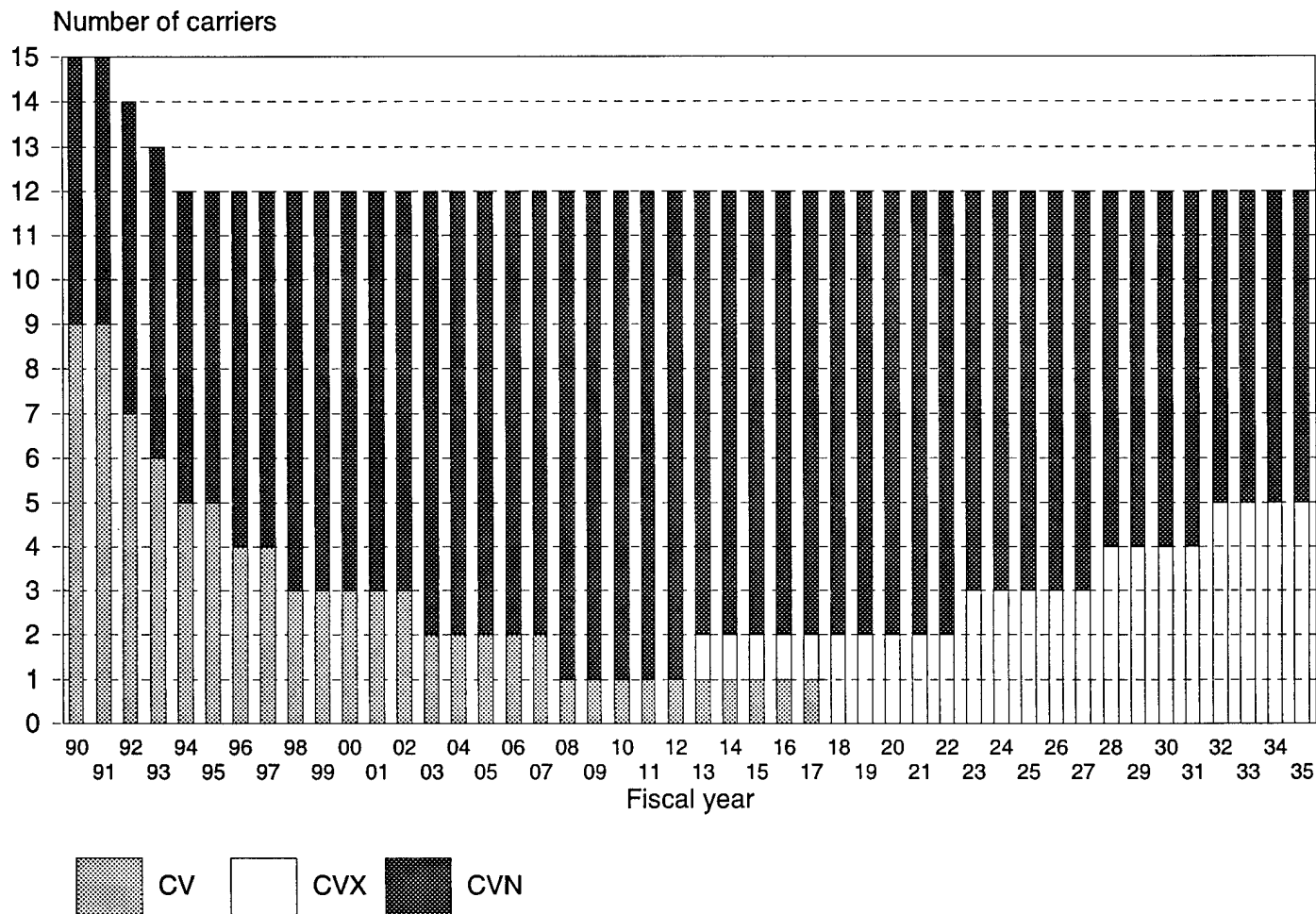
Source: Our analysis of U.S. Navy data.

The Navy is building two Nimitz-class nuclear-powered carriers, the Harry S. Truman (CVN-75) and the Ronald Reagan (CVN-76), which are scheduled to be delivered in fiscal years 1998 and 2003, respectively. In fiscal year 2001, the Navy will begin building the last Nimitz-design nuclear-powered carrier, CVN-77, estimated to cost over \$4.4 billion

(then-year dollars). The U.S.S. Nimitz (CVN-68) begins its 3-year refueling complex overhaul in fiscal year 1998 at the cost of \$2.1 billion (then-year dollars), followed by the U.S.S. Eisenhower (CVN-69) in fiscal year 2001 at the cost of \$2.3 billion (then-year dollars).

The formal design process for a new carrier class, designated the CVX, began in 1996. The CVX project received \$45.7 for fiscal year 1998 and \$190.2 has been requested for 1999. Construction of the first carrier of the new class, CVX-78, is expected to begin in 2006, with commissioning planned for 2013. The objective of this carrier project is to develop a class of aircraft carrier for operations in the 21st century that (1) maintains core capabilities of naval aviation, (2) improves affordability of the carrier force, and (3) incorporates an architecture for change. Another is to reduce life-cycle costs by 20 percent. The propulsion type for CVX-78 has not yet been decided. Notwithstanding the decision on the propulsion type for the CVX, a majority of the Navy's carriers will be nuclear-powered for at least the next 30 years (see fig. 1.4).

Figure 1.4: Illustrative Carrier Force Mix with CVX Carriers, 1990-2035



Source: Our analysis of Navy data.

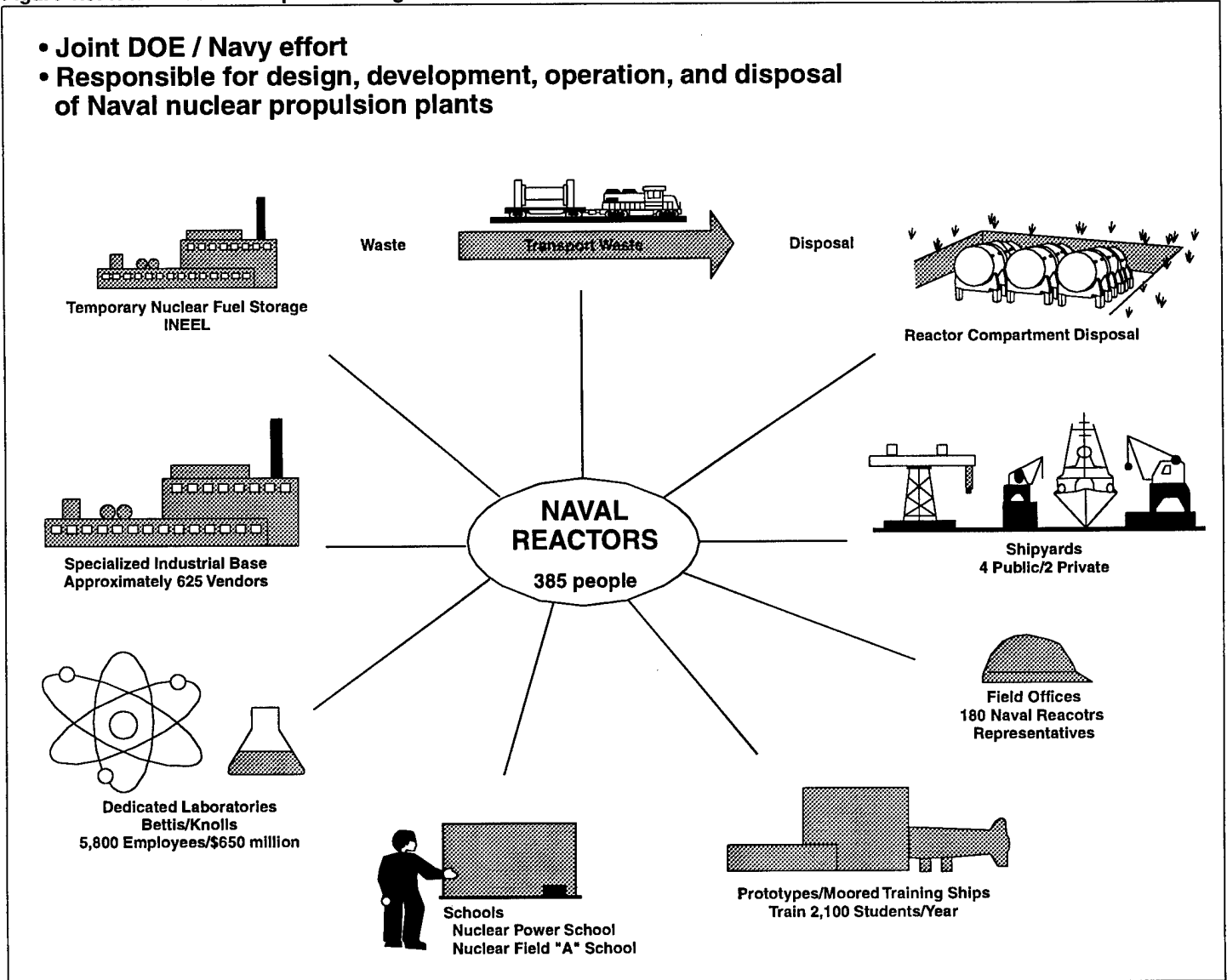
The Nuclear Propulsion and Aircraft Carrier Programs

The aircraft carrier program is managed by the Navy, but all programs having a nuclear component come under the jurisdiction of the Director, Naval Nuclear Propulsion Program, a joint Department of Energy (DOE) and Navy organization. The Director is assigned to design, build, operate, maintain, and manage all technical aspects of the Naval Nuclear Propulsion Program. Established in 1947, the Program delivered the first

nuclear-powered submarine in 1954 and the first nuclear-powered carrier, the U.S.S. Enterprise (CVN-65), in 1961. The U.S.S. Nimitz (CVN-68) was commissioned in 1975.

The Program, responsible for the cradle to grave management of all nuclear propulsion plants in the Navy, currently manages several laboratories, schools, shipyards, operating reactors, and vendors (see fig. 1.5). The Program is directly supported by two government-owned, contractor-operated laboratories dedicated solely to naval nuclear propulsion work, Bettis Atomic Power Laboratory and Knolls Atomic Power Laboratory. The laboratories have a combined workforce and annual budget of about 5,800 people and \$625 million. Their missions are to develop safe, militarily effective nuclear propulsion plants and ensure the continued safe and reliable operation of naval reactors. The missions are achieved through continuous testing, verification, and refinement of reactor technology.

Figure 1.5: Naval Nuclear Propulsion Program Infrastructure



Note: INEEL is the Idaho National Engineering and Environmental Laboratory.

Source: Navy and DOE.

Two other DOE laboratories support the Program, the Idaho National Engineering and Environmental Laboratory and the Pacific Northwest

National Laboratory Hanford Site. The Idaho National Engineering and Environmental Laboratory houses the Navy's expended core facilities. The Navy sends expended nuclear cores from retired or refueled reactors to that laboratory to measure fuel consumption and explore design improvements for future reactors. Until a few years ago, the cores were also reprocessed at the laboratory's facilities so that uranium from the cores could be recovered and recycled. Now, the expended fuel is held in temporary storage water tanks. The laboratory also provides other reactor and radioactive waste management support to the Program. The Hanford site is the ultimate repository of reactor compartments from decommissioned nuclear ships (less their highly radioactive expended fuel).

The Nuclear Power Debate

Propelling the Navy's aircraft carriers and surface combatants with nuclear power has been the subject of much debate. Key issues have been whether the cited operational advantages that nuclear power confers offset the increased costs of nuclear-powered surface ships and the value of battle groups composed of a mixture of nuclear-powered and conventionally powered fossil fuel ships.

Nuclear power advocates within DOD and the Navy have cited certain advantages to justify the nuclear-powered carrier program. They point out that nuclear-powered carriers have larger storage areas for aviation fuel and ordnance, can steam almost indefinitely without having to be refueled, and have superior acceleration, thereby enabling them to better recover aircraft. In a 1963 memorandum, the Secretary of the Navy advocated that the U.S.S. John F. Kennedy (CV-67) should be constructed with nuclear-power: "Increased range and staying power, plus a reduction in vulnerability provided by nuclear propulsion, will make naval forces much stronger and more useful as instruments of national policy and power."

Appendix II contains a detailed discussion of the advantages cited at that time for nuclear power in surface ships.

Others, however, balanced their desire for the benefits derived from nuclear propulsion against nuclear propulsion's increased costs. In January 1960, Admiral Arleigh Burke, Chief of Naval Operations, submitted a report on the attack aircraft carrier as part of his testimony

during congressional hearings before the House Committee on Appropriations.⁷ According to that report,

"[Nuclear power] does not provide a dramatic new mode of operation for the carrier as it does for the submarine. It does provide a greatly increased endurance before refueling, and the capability for long periods of steaming at high speeds. However, because of the aircraft fuel requirement, the tight logistic bonds of hydrocarbon fuels for the carrier are not severed by the use of nuclear propulsion."

"For this reason, the military tactics for aircraft carriers are not altered nearly so drastically by nuclear power as are those for submarines . . .

There are no misgivings about the existence of military advantages in a nuclear-powered aircraft carrier. These have been stated before, and are still true. In light of increasingly accurate knowledge of the additional cost, however, these military advantages simply do not compare well with the military potential in other needed areas which can be purchased for this money."

In regards to the cost of nuclear propulsion, Admiral Burke, who previously had advocated an all-nuclear surface fleet noted in 1960 that

" . . . budgetary considerations have forced us to review and weigh most carefully the inherent advantages of the nuclear-powered carrier against the additional cost involved in its construction. The nuclear-powered carrier would cost about \$743 million⁸ more than an oil-fired carrier. We can build into the conventionally powered carrier all of the improvements that have gone into the nuclear-powered U.S.S. *Enterprise* (CVN-65). . . except that nuclear plant. . . The funds gained in building this CVA with a conventional rather than a nuclear power plant have been applied in this budget to the procurement of other badly needed ships, aircraft, and missiles for the Navy."⁹

Even though the Navy still wanted nuclear propulsion, increasingly scarce resources necessitated a general belt tightening; the marginal costs of nuclear propulsion were not viewed as justifiable on the basis of the benefits derived, particularly when other needs had to be satisfied. The Secretary of Defense argued that the Navy could buy about five antisubmarine surface combatants—which were needed to defeat the grave threat posed by the expanding Soviet submarine force—with the

⁷U.S. Congress, House Committee on Appropriations, DOD Appropriations Bill, 1961, Hearings before a Subcommittee of the House Committee on Appropriations, 86th Cong., 2nd session, 1960. Part 2, p. 32.

⁸The original text cited \$130 million. We escalated the dollar amount to fiscal year 1997 dollars.

⁹U.S. Congress, House Committee on Appropriations, DOD Appropriations Bill, 1961, Hearings before a Subcommittee of the House Committee on Appropriations, 86th Cong., 2nd Session, 1960. Part 2, p. 19.

funds saved by buying a conventionally powered carrier rather than a second nuclear-powered carrier.

Three decades later, the dependence of surface combatants on at-sea replenishment remains. According to a 1992 Center for Naval Analyses study (CNA),¹⁰

“There seems to be little substance to the conventional wisdom that CVNs [nuclear carriers] are less demanding logistically than CVs [conventional carriers], and that, consequently, there may be significant savings and profound freedoms for employment relating to the battle force formed on the CVN. What might have been true for an all nuclear battle force, is of little consequence when examining an aircraft carrier accompanied by conventionally powered escorts.”

The study also concluded that

“Engaged battle forces need the support of many CLF [Combat Logistics Force] ships. All other things being equal, the presence of a few nuclear-powered units will not reduce the logistic pipeline, significantly. The increased capacity for ordnance and aviation fuel in the CVN design is not sufficient to untether the force from the pipeline. The hoped for increase in freedom of operational employment for CVNs is further restricted by the fossil-fuel dependence of the accompanying surface combatants.”

High Costs Led Navy to Stop Building Nuclear-Powered Surface Combatants

Throughout the 1960s and most of the 1970s, the Navy pursued a goal of creating a fleet of nuclear carrier task forces. The centerpiece of these task forces, the nuclear-powered aircraft carrier, would be escorted by nuclear-powered surface combatants and nuclear-powered submarines. In deciding to build nuclear-powered surface combatants, the Navy believed that the greatest benefit would be achieved when all the combatant ships in the task force were nuclear-powered. The Navy ceased building nuclear-powered surface combatants after 1975 because of the high cost. More recently, most of the remaining nuclear-powered surface combatants were decommissioned early because they were not cost-effective to operate and maintain.

Nuclear-powered surface combatants share many of the characteristics of the nuclear-powered carrier—unlimited high speed endurance, sustainability, and their larger size than their sister ships. The first nuclear-powered surface combatant was initially developed and fielded at about the same time as the first nuclear-powered carrier, in 1961. A total of

¹⁰Combat Logistics Force Ships for CV and CVN Battle Forces, CRM 91-257, dated February 1992.

nine nuclear-powered surface combatants were purchased with the final ship authorized in fiscal year 1975.

Nuclear-powered surface combatants were intended to be part of all nuclear-powered task forces, but this goal never materialized. In 1974, nuclear power seemed so promising that the Congress, in title VIII of the DOD Authorization Act for Fiscal Year 1975, stated that as a matter of policy all future U.S. warships intended to serve with the strike forces should be nuclear-powered. Exceptions would require a presidential finding that providing nuclear power was not in the national interest. On February 13, 1976, the President formally made a finding that constructing all nuclear surface combatants for the strike forces was not in the national interest. It was the Secretary of Defense's assessment that "the military value of an all nuclear-powered Aegis ship program does not warrant the increased costs or, alternatively, the reduced force levels." Further, he proposed a mixed propulsion program to provide nuclear-powered surface combatants, which could undertake crisis response and other operations in areas far from supply bases, and conventionally powered Aegis ships to supplement the nuclear-powered surface combatants in protection of high-value forces (including carriers) under conditions of sustained conflict. However, no more nuclear-powered surface combatants were acquired.

In fiscal year 1993, the Navy decided to decommission the newest class of nuclear-powered surface combatants instead of refueling them. These ships are being inactivated after an average of 17 years of service and with nearly half of their planned service life remaining. The decision was based on two factors—the need to reduce force structure in order to recapitalize the force and the ships' need for expensive nuclear refueling overhauls. Faced with declining budgets and large fiscal requirements, the Navy determined that the midlife modernization and upgrading through a refueling complex overhaul were not cost-effective. Even though there would be a near-term inactivation cost, the Navy would not incur the expense of a more costly refueling complex overhaul. Moreover, the decision would provide an opportunity to divest a large surface nuclear infrastructure supporting a small ship population. Another rationale for the decision to decommission the nuclear-powered surface combatant force was that a decision to invest in a refueling complex overhaul would drive retention of this force for the next 20 years. Operationally, the nuclear-powered surface combatants are expensive, and they are maintenance and infrastructure intensive ships. Personnel, training,

maintenance, and other supporting infrastructure costs were more expensive than their modernized, conventionally powered counterparts.

Objectives, Scope, and Methodology

The Defense Appropriations Act of 1994 Conference Report directed the Comptroller General to study the cost-effectiveness of nuclear-powered aircraft carriers. Overall, our objectives were to (1) evaluate the adequacy of conventionally and nuclear-powered aircraft carriers in meeting the Nation's forward presence, crisis response, and war-fighting requirements and (2) estimate the total life-cycle costs of conventionally and nuclear-powered aircraft carriers. The conferees noted the study should include (1) a life-cycle cost analysis, including the costs of processing and disposing of nuclear waste and spent fuel; (2) an estimate of the costs associated with processing and disposing of nuclear fuel and other nuclear material for the existing nuclear-powered fleet; and (3) the implications of an all nuclear carrier force on overseas homeporting.

To accomplish our objectives, we met with officials in DOD, State, and DOE and reviewed studies and reports concerning the U.S. military strategy, policy, employment concepts, missions, requirements, operations, characteristics, and costs relating to conventionally and nuclear-powered carriers. We also reviewed carrier peacetime deployment, surge, and war-fighting operations; performed several analyses controlling for the effects of propulsion type on conducting these operations; reviewed and evaluated conventionally and nuclear-powered carrier cost information; and, developed life-cycle cost estimates. (See app. I for a list of contacts and locations visited and a more detailed discussion of the methodology we used in our analyses.)

We performed our review in accordance with generally accepted government auditing standards.

Operational Effectiveness of Conventionally and Nuclear-Powered Carriers

Our analysis indicates that conventionally powered and nuclear-powered carriers both have been effective in meeting national security objectives and requirements, share many characteristics and capabilities, and that the Navy employs them interchangeably. Our analysis shows that conventionally and nuclear-powered carriers both have been effective in fulfilling U.S. forward presence, crisis response, and war-fighting requirements. Both carrier types embark the same standard air wing and train to the same mission requirements. We also found that each carrier type possesses certain advantages. For example, conventionally powered carriers spend less time in extended maintenance and, as a result, can provide more forward presence coverage. By the same token, nuclear carriers can carry larger quantities of aviation fuel and munitions and, as a result, are less dependent upon at-sea replenishment. Both types of carriers in the Persian Gulf War effectively performed their war-fighting missions.

We compared the two carrier types from the standpoints of their ability to fulfill U.S. forward presence, crisis response, and war-fighting requirements. Our comparison represents a historical perspective—the experiences of the Navy over the past several years operating a mixed force of conventionally powered and nuclear-powered ships.¹ That perspective addresses a broad spectrum of operations that includes providing routine peacetime presence, the Navy's response to emerging crises such as the movement of Iraqi forces to the Kuwait border in 1994, and the open conflict of Operation Desert Storm.

Both Types of Carriers Have Been Effective Fulfilling Forward Presence Requirements

Both conventionally and nuclear-powered carriers are employed overseas without consideration of propulsion type. Joint Staff and combatant command officials told us that the quality of presence provided by both types of carriers is indistinguishable. Conventionally powered carriers spend a smaller proportion of their time in depot-level maintenance than nuclear-powered carriers and, thus, are more available for deployment to meet presence and other fleet requirements. An all conventionally powered carrier force could either provide a greater level of overseas presence or require fewer carriers to meet U.S. peacetime presence requirements than would an all nuclear-powered force.

¹With the exception of the first nuclear carrier, the U.S.S. *Enterprise* (CVN-65), the nuclear carriers operating with the fleet have all been 90,000 ton-plus Nimitz-class ships—the Navy's most recent carrier class. Conversely, the conventional carriers operating in the fleets have included ships of the World War II-era Midway-class, the first large-deck carriers of the Forrestal-class, the subsequent Kitty Hawk-class, and the U.S.S. *Kennedy* (CV-67)—a ship that was originally designed for nuclear propulsion.

Both Carrier Types Satisfy Theater Commanders' Needs

The Navy has employed a mixed force of conventional and nuclear carriers since the U.S.S. *Enterprise*'s commissioning in 1962. During our discussions, officials of the Joint Chiefs of Staff, two unified commands, and the Navy could recall no instances since the *Enterprise*'s commissioning where the United States failed to achieve its objectives because a conventionally powered carrier, rather than a nuclear-powered carrier, was employed. Officials from the Joint Staff and at two unified commands said that a carrier's type of propulsion is not a critical factor in making employment decisions. The unified command officials said that their concern is the mix and number of aircraft on board the carrier and that both types generate the same number of aircraft sorties—the critical purpose of the aircraft carrier. They also said that they had never specifically requested the scheduling and deployment of a nuclear-powered, rather than a conventionally powered, aircraft carrier.

Overseas presence promotes regional stability by giving form and substance to the Nation's bilateral and multilateral security commitments and helps prevent the development of power vacuums and instability. It contributes to deterrence by demonstrating the Nation's determination to defend U.S., allied, and friendly interests in critical regions and better positions the United States to respond rapidly to crises. The presence posture enhances the effectiveness of coalition operations across the spectrum of conflict by promoting joint and combined training, encouraging responsibility sharing on the part of friends and allies, and facilitating regional integration.

The Pacific Command uses a "Forward Presence Matrix" as part of its cooperative engagement strategy for the Pacific Region. The matrix outlines the Command's goals and states how it intends to achieve them, including port visits, exercises with foreign navies, Navy-to-Navy talks, personnel exchanges, and community relations projects. According to Command officials, the matrix makes no distinction between conventionally and nuclear-powered carriers—it is not an important issue—the only issue is having a carrier as a tangible indicator of U.S. presence.

Unified command and Navy officials could not identify any instances where a presence mission or operation was adversely affected because a conventional rather than a nuclear carrier responded. However, many officials believed that a nuclear-powered carrier could respond more quickly over long distances and that because a commander is not

concerned about the ship's fuel consumption, a nuclear-powered carrier can "just do it."

Conventionally Powered Carriers Are More Available Due to Their Less Demanding Maintenance Requirements

Because their maintenance requirements are not as stringent and complex as those of nuclear-powered aircraft carriers, conventional aircraft carriers spend a smaller proportion of their time in maintenance than do nuclear aircraft carriers and, thus, are more available for deployment and other fleet operations.

During their service lives, aircraft carriers progress through a maintenance cycle of alternating operating intervals and depot-level maintenance periods.² In addition to the normal depot maintenance periods, nuclear-powered carriers must complete a refueling complex overhaul (RCOH) midway through their service lives.³ While the conventional carriers do not have a similar requirement, during the 1980s and early 1990s, six underwent modernization, five of which had their service lives extended through the Service Life Extension Program (SLEP).⁴ Given the large scope of its 1993 comprehensive overhaul and its expected service life, we included the U.S.S. John F. Kennedy (CV-67) among the six carriers.⁵

We compared the proportion of time the two carrier types spent in depot-level maintenance from October 1984 through December 1996 and found that, collectively, the ships of each type spent about 30 percent of their time undergoing depot-level maintenance. However, during that time, three conventional carriers underwent a SLEP while, because of their relatively short times in service, none of the Nimitz-class nuclear carriers

²Depot-level maintenance is normally performed in naval shipyards, private shipyards, or ship repair facilities. In addition to completing necessary repairs, modifications and alterations are made that improve the ships' capabilities. Because the procedures to maintain nuclear power plants are complex shipyard workers must be specifically trained to maintain nuclear carriers. Additionally, the materials used in nuclear carriers must meet exacting standards and the shipyards must have the facilities for the specialized work.

³During a nuclear reactor's operation, the nuclear material in the core splits or is "burned" as part of the fission process that produces the heat that generates the steam that powers the ship. Consequently, the core becomes progressively less efficient in generating the required heat and, therefore, at some point, must be replaced. Generally, a Nimitz-class carrier should be refueled after it has been in service for about 23 years, during the third complex overhaul (COH) or the fourth Docking Phased Incremental Availability (DPIA). Practically, the ship's operating tempo will also affect when it is refueled. In developing its maintenance schedules the Navy plans for a 32-month refueling period.

⁴The objective of a SLEP was to restore and preserve the carrier's mission capabilities so that it could remain a first-line, battle group ship for up to 45 years of service. The modernizations averaged 32 months—ranging from 24 to 42 months.

⁵The Kennedy now has a longer projected service life than the average of the carriers with a SLEP.

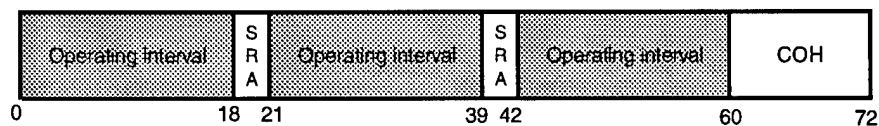
were refueled.⁶ When we adjusted the data to reflect the time they would typically have spent in an overhaul, the conventional carriers would have collectively spent 24 percent of their time in depot-level maintenance—about 6 percent less time than did the nuclear carriers with complex overhauls.

The difference between the two carrier types is generally consistent with their notional (planned) maintenance cycles. Figure 2.1 shows the notional (planned) maintenance cycle for conventional carriers extends over 72 months. The Nimitz-class nuclear carriers have been maintained within the parameters of an Engineered Operating Cycle (EOC), which, in its current form, extends over either 102 or 108 months, depending on the length of the overhaul at the end of the cycle. However, the Navy is changing the Nimitz-class maintenance cycle to an Incremental Maintenance Program (IMP), which will reduce the cycle time to 76.5 months.

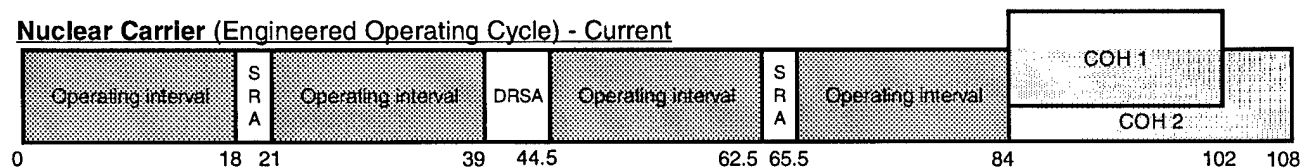
⁶We did not include the Forrestal's SLEP in this adjustment since it did not occur entirely within our time period.

Figure 2.1: Comparison of Nuclear and Conventional Aircraft Carrier Maintenance Cycles

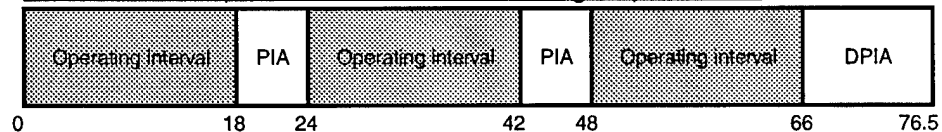
Conventional Carrier



Nuclear Carrier (Engineered Operating Cycle) - Current



Nuclear Carrier (Incremental Maintenance Program) - Planned



Notes:

COH = Complex Overhaul
 DPIA = Docking Planned Incremental Availability
 DSRA = Drydocking Selected Restricted Availability
 Operating interval generally includes a deployment
 PIA = Planned Incremental Availability
 SRA = Selected Restricted Availability

	Duration (in months)		
	CV	CVN (EOC)	CVN (IMP)
COH	12	18/24	na
DPIA	na	na	10.5
DSRA	4	5.5	na
Operating interval	18	18	18
PIA	na	na	6
SRA	3	3	na

Source: Navy data.

Because less depot-level maintenance is needed, conventionally powered carriers would be available for fleet operations about 5 percent more than nuclear carriers during a single maintenance cycle. As table 2.1 shows, this is consistent with the adjusted data for the October 1984 through December 1996 period.

**Table 2.1: Notional Carrier
Maintenance Cycles**

Type	Percent of time			
	Single maintenance cycle ^a		Over service life ^b	
	Available for operations	In depot maintenance	Available for operations	In depot maintenance
CV	75	25	74	26
CVN ^c				
EOC	69	31	^d	^d
IMP	71	29	69	31

^aBased on one cycle, as shown in figure 2.1.

^bOur analysis assumed a carrier's service life is to be 50 years for either conventional or nuclear power. The depot-level maintenance includes a SLEP for the conventional carriers and a RCOH for the nuclear carriers.

^cAll data is for Nimitz-class only and does not include U.S.S. Enterprise (CVN-65).

^dNot calculated.

Source: Our analysis of Navy data.

Conventionally Powered Carrier Force Could Provide More Overseas Presence Than a Like-Sized Nuclear Force

An all conventionally powered carrier force could either provide a greater level of overseas presence or require fewer carriers to meet U.S. peacetime presence requirements than would an all nuclear-powered force. Providing the carriers needed to meet U.S. forward presence objectives in peacetime is an important determinant of the Navy's carrier force structure. In its 1993 Bottom-Up Review, DOD concluded a force of 10 aircraft carriers could meet the military's war-fighting requirements, but it retained 12 carriers (11 active carriers plus 1 deployable training carrier) to meet the larger peacetime forward presence requirements in the three principal overseas theaters.⁷ (Those theaters include the Western Pacific, Indian Ocean, Persian Gulf, and Mediterranean Sea.) Currently, these carriers provide substantial, although not continuous presence.⁸ The Global Naval Force Presence Policy sets priorities and provides scheduling guidance.

⁷DOD's report on the recently completed Quadrennial Defense Review stated that the Navy would maintain a force of 12 aircraft carrier battle groups.

⁸DOD's Bottom-Up Review concluded that, with a 12-carrier force, the Navy could provide full-time coverage in one of the three regions while there would be a minimum of a 2-month gap in coverage during a year in each of the other two regions. According to the Global Naval Force Presence Policy, during gaps, a carrier battle group in another theater must be able to reach the "gapped" theater within a specified time frame.

Global Naval Force Presence
Policy

During peacetime, the Chairman of the Joint Chiefs of Staff, service chiefs, and chiefs of the five unified geographic commands establish long-range planning guidance for the location and number of U.S. naval forces assigned to all regions on a fair-share basis.⁹ This scheduling guidance—Global Naval Force Presence Policy—can be adjusted, as necessary, to meet unexpected contingencies. This policy results in planned gaps in various theaters, particularly in the Mediterranean Sea and the Indian Ocean. The policy represents a balanced distribution of naval assets while preserving personnel policy objectives. The policy does not differentiate between conventional and nuclear carriers.

The naval forward presence requirements articulated by the Commanders in Chief of the European, Central, and Pacific Commands largely determine how the Navy deploys to meet its global commitments. The commanders base their requirements on the strategic objectives set for their theaters by the National Command Authorities¹⁰ and the strategic situation in their theaters. According to a Navy doctrinal publication, "Overseas presence promotes national influence and access to critical global areas, builds regional coalitions and collective security, furthers stability, deters aggression, and provides initial crisis-response capability." The commanders believe that sustained, forward deployed, combat ready forces are vital to achieving these goals and are critical to ensuring timely crisis response.

In its August 1994 assessment, Naval Forward Presence Report, DOD analyzed peacetime presence options for naval forces to meet the five geographic unified commands' unconstrained requirements for naval presence. It concluded that the unified commands' naval force requirements generally exceeded the levels of available assets. The report stated that

"the totality of this set of all-encompassing requirements is beyond what could be reasonably covered by naval forces alone, it is a representation of the broad scope of presence missions confronting the theater commander" and that "any exercise in determining alternative force structures must necessarily account for other service contributions"

⁹There are a total of nine unified combatant commands, five of which are called geographic unified commands, or theater commands. The five theater commands are the Atlantic, Central, European, Pacific, and Southern Commands. The commanders in chief of these commands are responsible for all operations within their designated geographic areas.

¹⁰The President and the Secretary of Defense or their duly deputized alternates or successors constitute the National Command Authority.

The assessment also stated that the most important overseas presence requirements can be met through a range of measures, including “tethers,”¹¹ other service forces, and greater acceptance of periodic presence in some cases. Changing assumptions, such as operating tempo, availabilities, and originating ports and destinations, can also alter conclusions about force requirements. The Navy has periodically assessed naval force requirements using a model to calculate the total force necessary to meet the unified commands’ presence requirements for given assumptions and inputs.

The Navy deploys one carrier battle group and one amphibious ready group with an embarked, special operations-capable Marine expeditionary unit for a substantial portion of each year in the three theaters. According to the presence policy, if neither a carrier battle group nor an amphibious group is near an unfolding crisis, an equivalent force can be deployed to the vicinity on short notice from another theater.

An important constraint that bounds the ability to employ carriers in support of forward presence is Personnel Tempo of Operations (PERSTEMPO). The Navy initiated the PERSTEMPO Program in 1985 to balance support of national objectives with reasonable operating conditions for naval personnel, coupling the professionalism associated with going to sea with a reasonable home life. The Program is built around the following goals:

- a maximum deployment length of 6 months,
- a minimum turn around ratio of 2.0:1 between deployments, and
- a minimum of 50 percent time in homeport for a unit over a 5-year cycle.

The importance the Navy places on meeting PERSTEMPO goals is found in the presence policy that states that in scheduling carriers to meet these presence requirements, “CNO Perstempo goals remains inviolate.”

Calculating Aircraft Carrier Overseas Presence Requirements

Our analysis of force requirements estimates for overseas presence, derived from the Navy’s Force Presence Model, shows an all conventional carrier force could either provide a greater level of overseas presence or require fewer carriers to meet U.S. peacetime presence requirements than

¹¹Tether refers to the practice of maintaining ships at acceptable distances away from a specific area of presence operations while allowing them to return within a specified number of days. The tethered presence policy is a Chairman, Joint Chiefs of Staff, and DOD policy that is supported by funding in the fiscal year 1998 budget and the Future Years Defense Program for fiscal years 1998 through 2003. This policy results in lower force level requirements than those needed to support continuous presence in all three major regions.

would an all nuclear carrier force.¹² Several variables enter into the equation that calculates the carrier force level required to attain a level of peacetime presence. These variables include the time spent in depot-level maintenance, the restrictions imposed by the PERSTEMPO policy, the distance carriers must transit from their U.S. homeports to the overseas theater, the speed of the transit, and the length of deployment. Depot-level maintenance time is the single distinguishing variable when calculating conventionally and nuclear-powered carrier requirements.

As table 2.2 shows, an all conventional carrier fleet generally could provide about 9 percent more presence coverage—an average of 32 days—in the European and Central Commands, while providing full-time coverage in the Western Pacific, than could an all nuclear fleet.

**Table 2.2: Presence Coverage
Provided by Deployable Forces of 12-,
11-, and 10-Conventional and Nuclear
Carriers**

Deployable carriers ^b	Annual presence coverage ^a			
	All conventional force		All nuclear force	
	Days	Percent	Days	Percent
12	369	101	336	92
11	336	92	303	83
10	303	83	274	75

^aCoverage provided to both the European and Central Commands over the course of a year. Includes a carrier homeported in Japan providing full-time presence in the Western Pacific. This example assumes that a nuclear-powered carrier can be permanently forward deployed in Japan. (Ch. 4 discusses the implications of this assumption in greater detail.)

^bAn additional carrier would be added to the above levels for each one that is in SLEP or RCOH or that serves as a dedicated training carrier.

Source: Our analysis using the Force Presence Model.

Table 2.3 shows the results of our analysis of the comparative number of carriers needed to provide various levels of overseas presence. Our estimates indicate that an all conventional carrier fleet generally needs about one less carrier to provide presence in the European and Central Commands and the Western Pacific than would an all nuclear fleet.

¹²The Navy uses this model to estimate the number of ships needed to provide overseas presence under specific conditions.

Chapter 2
Operational Effectiveness of Conventionally
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Table 2.3: Number of Deployable Carriers Required to Provide 100, 80, and 60 Percent Presence Coverage

	100 Percent ^a			80 Percent ^a			60 Percent ^a		
	CVN			CVN			CVN		
	CV	EOC ^b	IMP ^c	CV	EOC ^b	IMP ^c	CV	EOC ^b	IMP ^c
Number of carriers ^d	12	13	13	10	11	11	8	9	9

^a Percentage of time a carrier is present in European and Central Commands' areas of responsibility. Totals include the one carrier homeported in Japan, providing 100-percent presence coverage to the Western Pacific, regardless of propulsion type. (See ch. 4 for more information.)

^b Nuclear carrier maintained under the EOC strategy.

^c Nuclear carrier maintained under the IMP strategy.

^d Rounded up to the next whole carrier. An additional carrier would be added to the above levels for each one that is in a SLEP or a RCOH or that serves as a dedicated training carrier.

Source: Our analysis using the Force Presence Model.

Neither the number of deployable carriers shown in table 2.2 nor the totals shown in table 2.3 provide for such needs as a training carrier or take into account extended maintenance periods such as nuclear carrier refuelings or conventional carrier service life extensions.^{13, 14} Meeting those needs could require an additional one or two carriers.

To minimize any factors other than propulsion type that could influence the number of carriers needed to provide forward presence, we based our calculations on the Navy's standard transit distances and the standard fixed transit speed of 14 knots.¹⁵ The only delay we included in the transits was a 1-day delay for transiting the Suez Canal where appropriate.¹⁶ The total requirement for the European and Central Commands is based on the assumption that Atlantic and Pacific Fleet ships would meet the presence requirements of those two Commands in the same proportion as they are currently scheduled for in the 1996 to 2000 time frame. We used the Navy's

¹³The Navy considers that it needs one carrier to meet the needs of the pilot training pipeline and to fill occasional gaps in its ability to meet peacetime presence requirements with the other carriers, as demonstrated by the Kennedy's recent deployment.

¹⁴One conventional carrier was nearly continuously in SLEP while that program was underway. As the nuclear carrier fleet ages into the 21st Century, a similar situation will exist from a refueling overhaul standpoint.

¹⁵Our calculations assume that the carriers are homeported in Norfolk, Virginia, and San Diego, California.

¹⁶This delay occurred when an Atlantic Fleet carrier entered the Central Command's area of responsibility or when a Pacific Fleet carrier provided presence in the Mediterranean Sea.

notional values, as inputs for operation cycle length (IMP cycle for nuclear carriers), deployment length, number of deployments per cycle, and overhaul length.

Several Factors Affect the Time Needed for the Carrier Force to Respond to a Crisis or Major Theater War

Several factors affect how quickly both types of carriers can respond to a crisis or mobilize for a major theater war. One factor is the speed the carrier and its accompanying battle group can maintain during their voyage to the crisis. Another factor is the degree to which any on-going depot-level maintenance periods and training periods can be shortened to accelerate deployment of the carrier.

Nuclear-Powered Carrier's Unlimited High Speed Range Reduces Transit Times

Because nuclear-powered carriers do not need to slow for underway replenishment of propulsion fuel, they can transit long distances faster than can conventional carriers. Even though both types have similar top speeds, a conventional carrier normally slows to a speed of about 14 knots during underway replenishment. Our analysis showed that a conventional carrier, steaming at 28 knots, would arrive about 6 hours later than a nuclear carrier on a 12,000-nautical mile (nm) voyage (the distance from San Diego, California, to the Persian Gulf) and would have been refueled three times. On a 4,800-nautical mile voyage (the distance from Norfolk, Virginia, to the eastern Mediterranean Sea), the conventional carrier, steaming at 28 knots, would arrive about 2 hours later than a nuclear carrier. As table 2.4 shows, in most cases, a nuclear carrier completes a transit more quickly than does a conventional carrier.

Table 2.4 compares carrier transit times only. Carriers being escorted by conventionally powered surface combatants would transit more slowly because of the escorts' need to replenish more frequently. As a result, the overall transit speeds of both types of carrier battle groups would be slower than those shown, if all of the ships in the battle group were to arrive in the same vicinity at about the same time. A comparison of transit times of nuclear and conventional carriers that have responded to several crises in this decade is presented in appendix IV.

Table 2.4: Comparison of Nuclear and
Conventional Carrier Transit Times

Transit distance (nm)	Transit speed (knots)	Transit time (days)		CV refuelings ^b
		CVN	CV ^a	
4,800 (Norfolk, Va., to the Eastern Mediterranean Sea)				
	20	10.0	10.0	0
	24	8.3	8.4	1
	28	7.1	7.2	1
8,600 (Norfolk, Va., to the Persian Gulf via the Suez Canal) ^c				
	20	17.9	18.0	1
	24	14.9	15.0	1
	28	12.8	13.0	2
12,000 (San Diego, Calif., to the Persian Gulf) ^c				
	20	25.0	25.1	2
	24	20.8	21.0	2
	28	17.9	18.1	3

^aTransit time is based on the conventional carrier slowing to 14 knots for the duration of each refueling.

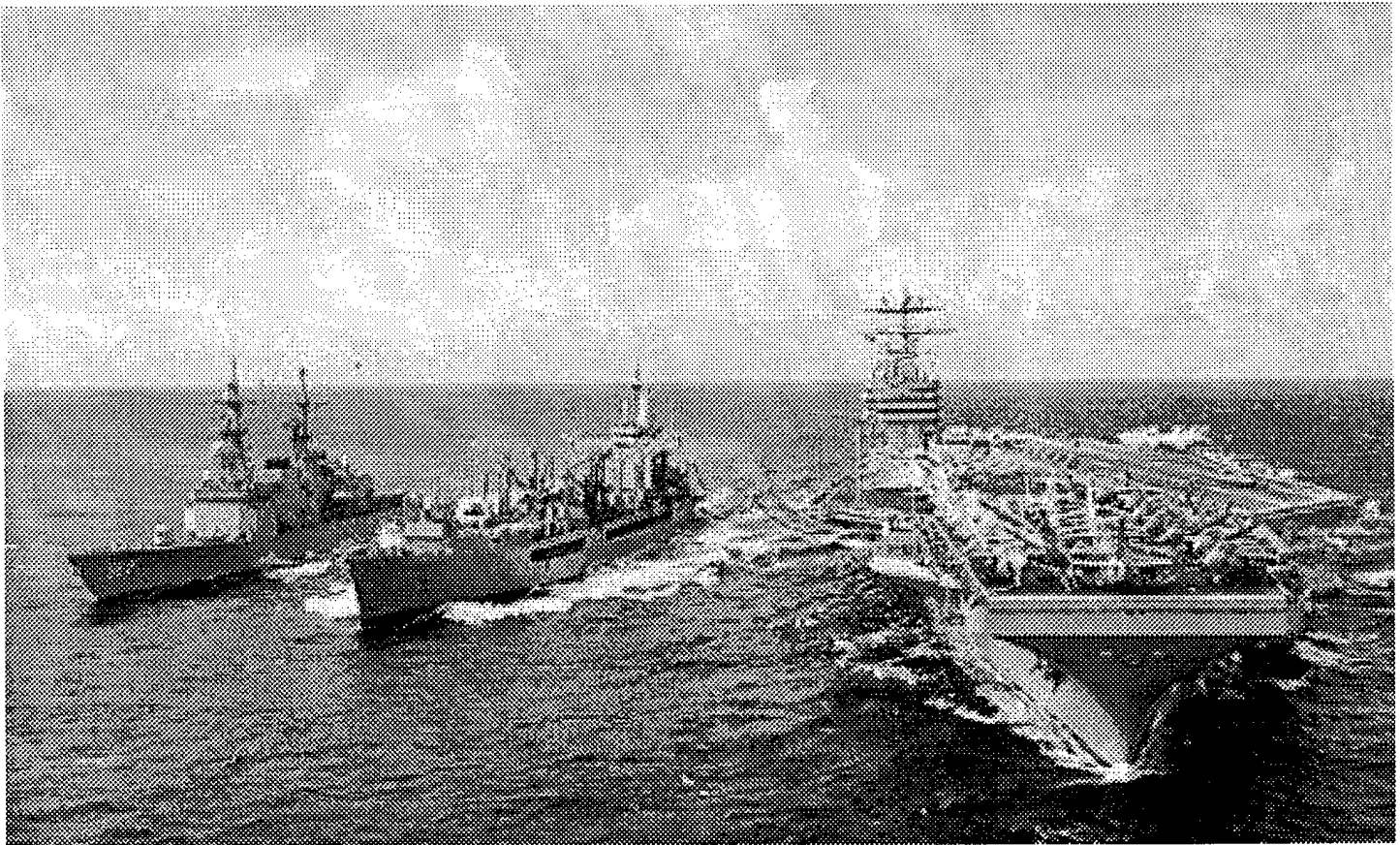
^bThe number of refuelings required is based on refueling the conventional carrier when its propulsion fuel level reaches 30 percent of capacity.

^cThis distance is to the central part of the Gulf.

Source: Our analysis of Navy data.

Figure 2.2 shows an oiler providing simultaneous replenishment with a Spruance-class destroyer and the nuclear-powered carrier U.S.S. George Washington (CVN-73) while transiting the Atlantic Ocean.

Figure 2.2: An Oiler Providing Simultaneous Replenishment to a Surface Combatant and the Nuclear-Powered Carrier U.S.S. George Washington (CVN-73)



Source: Navy photo.

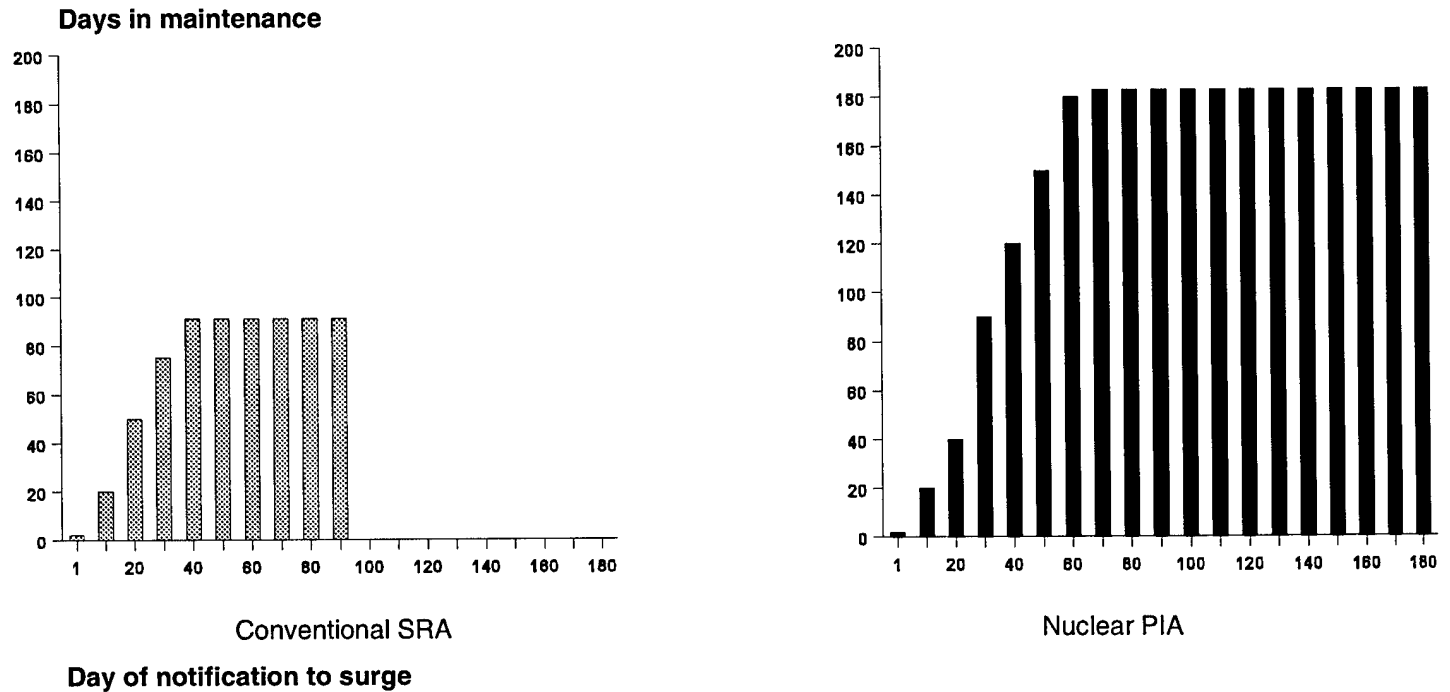
A Conventionally Powered Carrier Can More Easily Surge From Maintenance

If a carrier is required in an emergency, maintenance periods can be shortened by varying degrees, depending on the stage of the maintenance being performed. Navy officials said that it is easier to shorten the conventional carriers' maintenance periods than it is for those of the nuclear carriers and that this is an important factor governing the carriers' ability to respond to a major crisis. The degree to which a carrier undergoing depot-level maintenance can be "surged" for deployment by shortening that maintenance period depends on how much of the period has been completed when the surge decision is made. For both types of carriers, the decision must be made early if the period is to be

substantially shortened. However, Navy officials said, and documents show, that due to the complexity of its maintenance, a nuclear carrier's maintenance period cannot be shortened to the same degree as that of a conventional carrier. Also, a nuclear carrier's refueling overhaul cannot normally be shortened or accelerated since rushing the process would be neither economical nor prudent from a safety standpoint.

Figure 2.3 illustrates the degree to which a conventional aircraft carrier can be surged out of an ongoing Selected Restricted Availability (SRA) and a nuclear aircraft carrier can be surged out of an ongoing Phased Incremental Availability (PIA) when the decision to do so is made at various times during the normal duration of those maintenance periods. The periods can be substantially shortened only if the decision is made early in the maintenance periods. Maintenance on both carrier types could be considerably curtailed if less than 15 percent of the scheduled maintenance time had been completed. However, a nuclear carrier's maintenance would normally proceed to its normal completion after about 33 percent of its scheduled maintenance had been completed, while a conventional carrier could complete up to 40 percent of its maintenance before proceeding to its normal completion. The figure also shows that a conventional carrier undergoing an SRA could be available to the fleet much quicker in an emergency than a nuclear carrier undergoing a PIA.

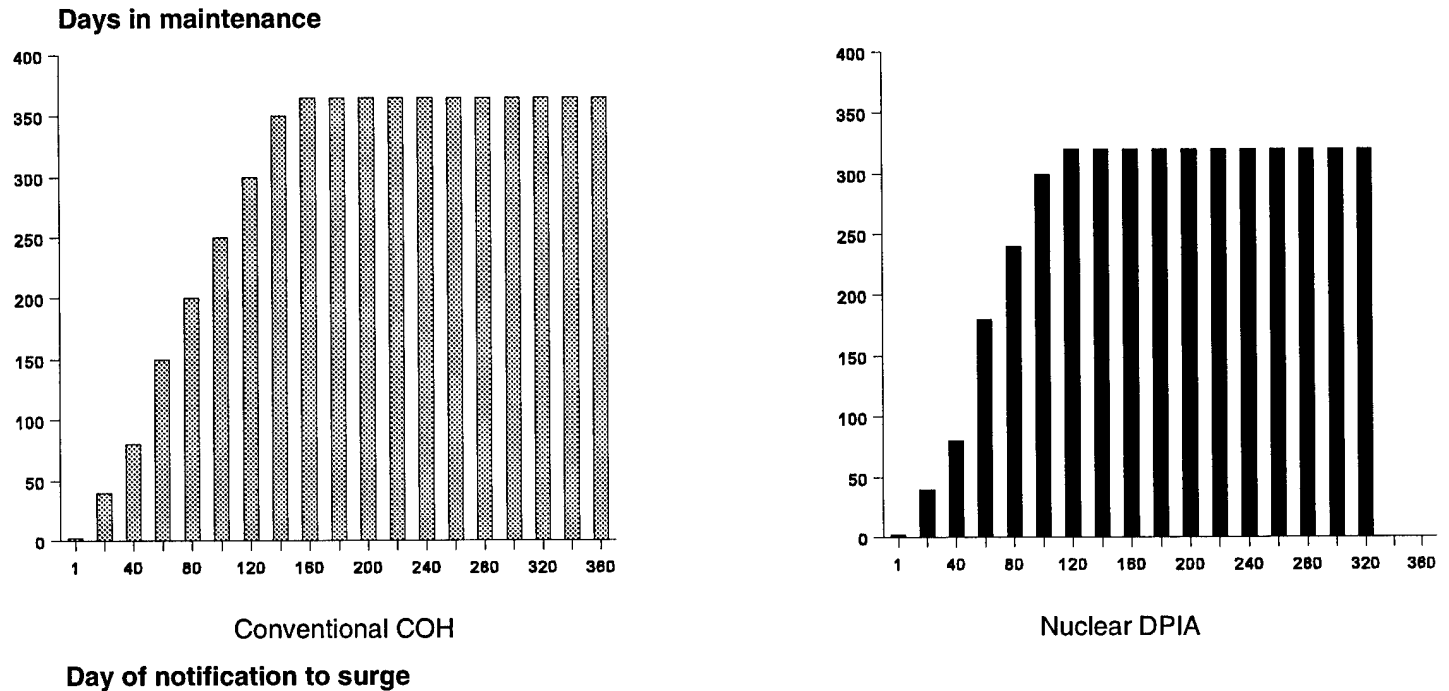
Figure 2.3: Comparative Ability to Surge From an SRA and a PIA



Source: Our analysis of Navy data.

Figure 2.4 illustrates the difference in the ability between a conventional carrier undergoing a COH and a nuclear carrier undergoing a DPIA to surge from maintenance. Again, the decision to accelerate the maintenance period must be made early—before 15 percent is completed—if it is to be substantially shortened. Additionally, the periods will proceed to normal completion after about 33 and 40 percent of the nuclear and conventional carriers' maintenance periods, respectively, have been completed.

Figure 2.4: Comparative Ability to Surge From a COH and a DPIA



Notional duration
COH - 12 months
DPIA - 10.5 months

Source: Our analysis of Navy data.

As the two figures show, while a conventional carrier can be more easily surged out of an SRA than a nuclear carrier can be surged out of a PIA, the reverse is true when a carrier is in either a COH or a DPIA. However, as figure 2.1 shows, SRAS and PIAS are the most common types of depot maintenance periods. Thus, from an overall depot-level maintenance standpoint, conventional carriers could more readily mobilize in response to a major crisis.

Both Types of Carriers Train to Common Requirements

The degree to which interdeployment training can be compressed is unrelated to a carrier's type of propulsion. Crews of nuclear and conventional carriers undergo the same interdeployment training except for training specifically related to the power plants. Two important factors in compressing interdeployment training are an air wing's proficiency and the turnover in the ship's crew since the last deployment.

The Navy's Aircraft Carrier Training and Readiness Manual, which does not differentiate between nuclear and conventional carriers, describes the interdeployment training cycle. The cycle progresses through three phases of training—unit, ship and air wing, and battle group. The cycle also includes other activities such as in-port periods and preparation for deployment. Despite the common training program, our analysis of interdeployment cycle data since fiscal year 1984 shows that interdeployment training periods of conventional carriers have averaged 9.8 months while those of nuclear carriers have averaged 10.6 months.

Conventionally and Nuclear-Powered Carriers Were Both Effective in the Persian Gulf War

The Navy generally adhered to peacetime carrier deployment and maintenance schedules that had been established before Iraq invaded Kuwait and did not take any special actions to ensure a greater nuclear carrier presence during Operations Desert Shield and Desert Storm. Our review of data summarizing carrier operations and support during Desert Storm showed that both types of carrier were effective in their war-fighting missions. Details about the carriers' participation in Desert Storm are contained in appendix V.

Given the presence of U.S. Air Force and allied aircraft, geographic constraints, and the relatively benign threat environment in the Persian Gulf and Red Sea carrier operating areas, Desert Storm may not be representative of the type of conflict in which nuclear carriers could demonstrate any of its operational advantages over conventional carriers. However, Desert Storm represents the most extensive and extended combat use of carrier aviation since the Vietnam conflict—before nuclear carriers comprised a significant portion of the U.S. carrier fleet. Additionally, it is the prototype of one of the two major theater wars or dangers that have been, and continue to be, a key element of U.S. military policy since the demise of the Soviet Union. Furthermore, Navy doctrine states the future role of naval forces has shifted from the Cold War-era independent blue-water, open-ocean naval operations on the flanks of the Soviet Union to a new emphasis on joint littoral operations in an expeditionary role against regional challenges. Thus, the nature of Desert

Storm portends the types of conflict in which U.S. forces expect to be engaged in the foreseeable future.

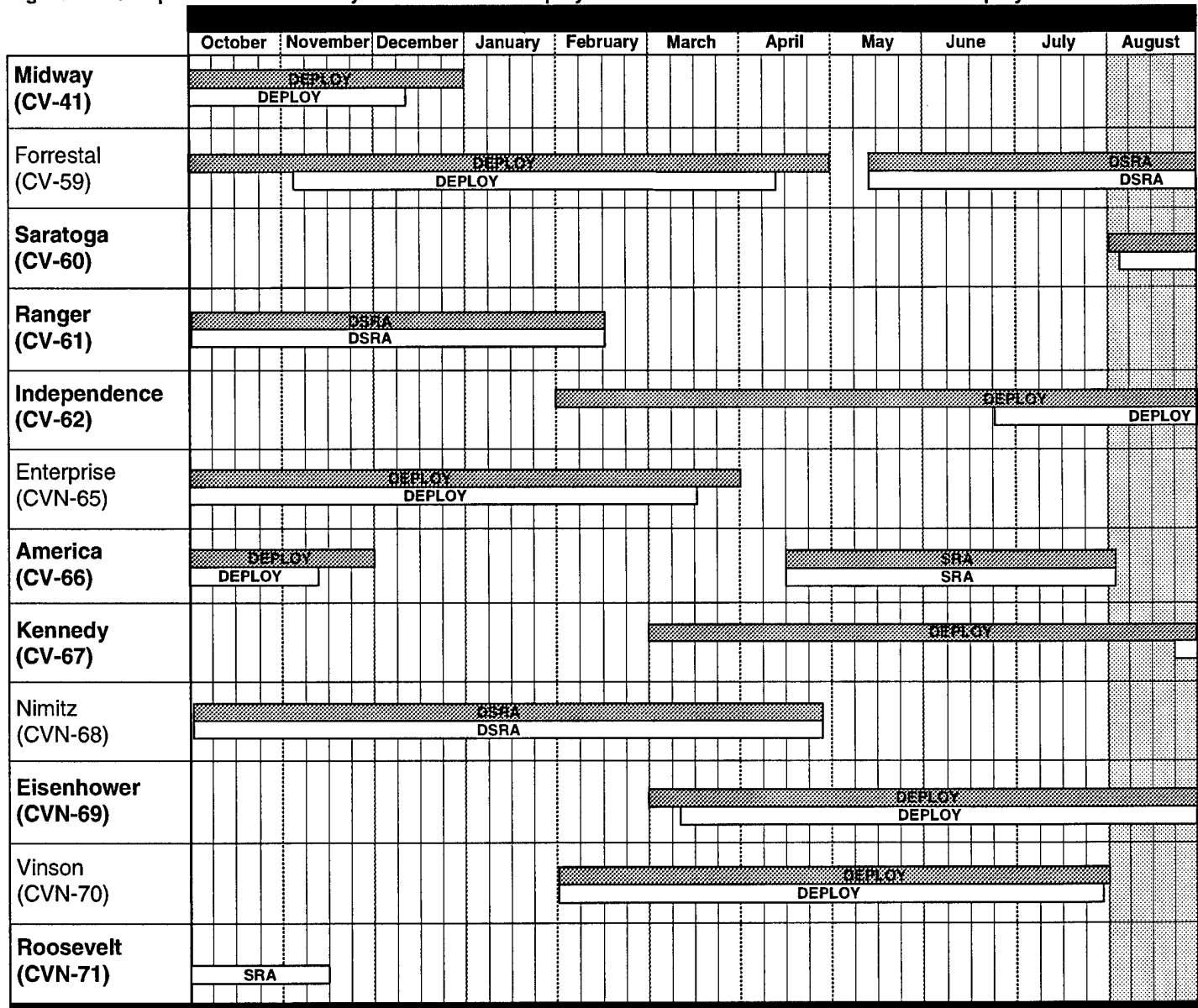
**Pre-Established Carrier
Schedules Were Followed
to Respond to Desert
Shield/Desert Storm**

According to DOD's April 1992 report to the Congress entitled Conduct of the Persian Gulf War, during the first 2 months after the Iraqi invasion, the Commander in Chief, Central Command, believed there was a "window of vulnerability" when it was uncertain whether Coalition forces could defeat an Iraqi invasion of Saudi Arabia. As shown in figure 2.5, carriers generally deployed, returned from deployment, and began maintenance as scheduled during this period.

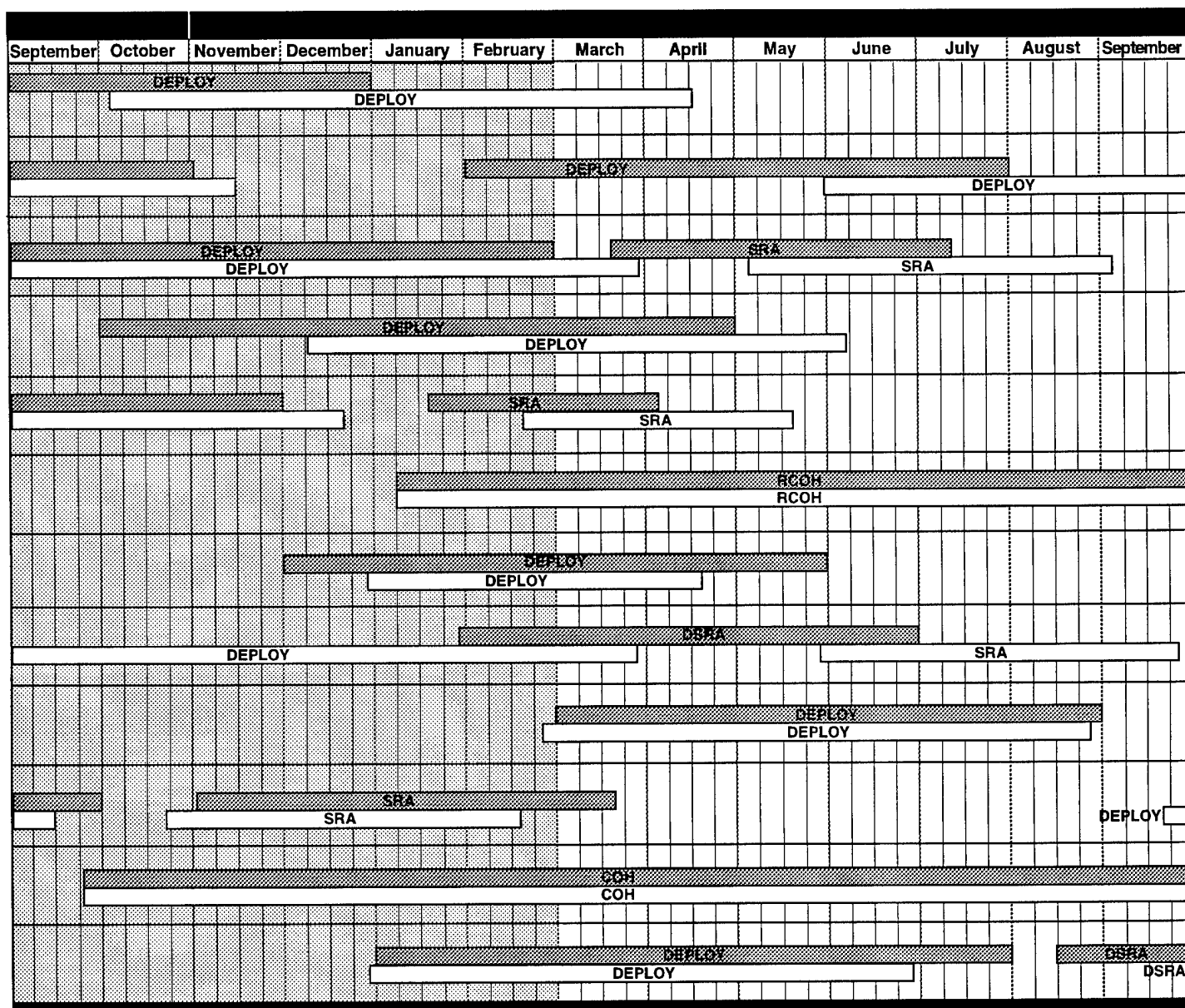
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Figure 2.5: Comparison of Previously Planned Carrier Deployments With Actual Desert Shield/Storm Deployments



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Operational Effectiveness of Conventionally
and Nuclear-Powered Carriers



Desert Shield/Desert Storm

- Actual
- Planned
- COH Complex Overhaul
- DSRA Drydocking Selected Restricted Availability
- Deploy Deployment
- PSA Post Shakedown Availability
- RCOH Refueling Complex Overhaul
- SRA Selected Restricted Availability

(Figure notes on next page)

Note 1: Carriers' names highlighted in bold participated in Desert Shield/Desert Storm.

Note 2: This schedule does not include either the Kitty Hawk (CV-63) which was undergoing Service Life Extension Program (SLEP) during the entire period, or Constellation (CV-64) which entered SLEP on July 1, 1990.

Note 3: Planned deployment dates reflect the first day of the month when the deployment is to start, and the last day of the month when the deployment is to end.

Source: Our analysis of Navy data.

The Navy had several opportunities for a greater nuclear carrier presence in Desert Shield/Desert Storm but followed established deployment and maintenance schedules, as discussed below.

- The U.S.S. Eisenhower (CVN-69) was well into a scheduled 6-month deployment when Iraq invaded Kuwait. The Eisenhower entered the Red Sea on August 8th, remaining for 16 days, until relieved by the U.S.S. Saratoga (CV-60). Instead of being retained in theater during the initial period of uncertainty and concern following the invasion, the Eisenhower immediately departed for Norfolk and began shipyard maintenance in late October. Two conventionally powered carriers, the U.S.S. Kennedy (CV-67) and the Saratoga, were deployed for 7-1/2 months throughout all of Desert Shield/Desert Storm.
- The U.S.S. Carl Vinson (CVN-70) returned from a 6-month deployment on July 31, 1990, just 2 days before the Iraqi invasion. According to the Navy's tactical training manual, "Selected units [ships] returning from deployment can be retained for a period in a surge readiness status to meet contingency requirements." Instead, nonessential materials and supplies were offloaded during August and September, and the ship began a complex overhaul on September 29, 1990, lasting until April 1993.
- The U.S.S. America (CV-66) completed shipyard maintenance on August 2nd, the day of the Iraqi invasion, and underwent a significantly compressed 5-month training period, deploying for the war in December 1990. In contrast, the U.S.S. Nimitz (CVN-68), which had completed scheduled shipyard maintenance in April 1990, was used to qualify Reserve and student pilots in carrier landings for most of August and spent all of September and most of October in port in Bremerton, Washington. The ship did not deploy until February 25, 1991, 3 days before the end of the war.
- The U.S.S. Enterprise (CVN-65) arrived in Norfolk in March 1990, after completing a 6-month around-the-world deployment from Alameda, California. From the time of its arrival in Norfolk until the start of a RCOH

in January 1991, the ship spent over 7 months in port, and about 1 month at sea conducting carrier landing qualifications and independent steaming activities. The Enterprise became nonoperational on August 15, 1990, less than 2 weeks after the Iraqi invasion, when the crew began removing everything not needed for the overhaul, which lasted over 3-1/2 years.

Ultimately, the Navy deployed six carriers to fight in Desert Storm—the nuclear-powered U.S.S. Theodore Roosevelt (CVN-71) and five conventionally powered carriers: the World War II vintage U.S.S. Midway (CV-41), the U.S.S. Saratoga (CV-60), the U.S.S. Ranger (CV-61), the U.S.S. America (CV-66), and the U.S.S. John F. Kennedy (CV-67).

Logistics Support of All Carriers Was Comparable

The Navy operated and supported all six carriers in essentially the same manner. Each carrier battle group was assigned its own dedicated support ships, which enabled frequent replenishment of fuel and ordnance.

All carriers were replenished about every 3 to 3-1/2 days, well before fuel and ordnance reached critical levels. Using Center for Naval Analyses-generated fuel and ordnance consumption rates, we estimate that the nuclear-powered U.S.S. Theodore Roosevelt (CVN-71) expended about 8 percent of its jet fuel and 2 percent of its ordnance per day, while the conventional carriers expended about 15 percent of their jet fuel and 5 percent of their ordnance per day. It is our observation that the carriers were resupplied whenever the opportunity arose, in accordance with naval doctrine, to maintain a high state of readiness.

Air Operations Were Comparable Among the Carriers

The distance to targets and the number of aircraft assigned to each carrier were primarily responsible for the differences in sorties launched by each carrier. Carriers operating in the Persian Gulf generated more missions than the Red Sea carriers because they were considerably closer to their targets. While the Roosevelt launched more sorties than any other carrier, it, along with the Kennedy, had the most aircraft assigned aboard (78). The Roosevelt operated in the Persian Gulf, while the Kennedy operated in the Red Sea. In contrast, two other Persian Gulf carriers, the Midway and the Ranger, had only 56 and 62 aircraft, respectively. When sorties were averaged based on the number of aircraft assigned, each of the Persian Gulf carriers averaged about 53 sorties per aircraft.

None of the carriers operated around-the-clock. Instead, they rotated on an operating schedule that would enable them to have intervals of off-duty

time for rest and replenishment. When sorties were analyzed based on operating days, the Roosevelt averaged 106 sorties per day compared to 89 for the Midway. However, the latter had 22 fewer aircraft aboard. When the number of assigned aircraft was considered, the Midway led all carriers with an average of 1.59 sorties per aircraft per operating day, followed by the Ranger with 1.41 sorties, and the Roosevelt with 1.36 sorties.

Conventionally and Nuclear-Powered Carriers Share Many Similar Characteristics and Capabilities but Differ in Others

Even though the nuclear carriers are newer and larger than the conventional carriers, the two ship types have several common characteristics and capabilities. They are similar in that they

- are subject to the same operational guidance;
- carry the same number and types of aircraft in their air wing and can generate the same number of sorties;
- have top speeds in excess of 30 knots;
- do not differ with respect to their survivability; and
- can produce adequate supplies of fresh water.

However, there are some differences. For example, nuclear carriers

- have larger storage areas for aviation fuel and ordnance and
- are better able to recover landing aircraft due to their superior acceleration.

The similarities in these key features have allowed the Navy to employ both types of carriers interchangeably for routine deployments overseas and employment in contingency operations.

Operational Guidance Does Not Distinguish Between Carrier Types

When establishing the required capabilities of aircraft carriers, providing operational guidance, and preparing plans for employing them, the Joint Chiefs of Staff, unified commanders, and the Navy do not distinguish between conventional and nuclear carriers. Both carrier types are expected to carry out the same tasks, operate under similar conditions, and are allocated to peacetime presence missions and wartime tasks irrespective of propulsion type. For example, the document that discusses carrier missions and required operational capabilities states that the mission of multipurpose aircraft carriers is to operate offensively in a high density, multithreat environment. It lists specific tasks and readiness requirements but does not distinguish between the two carrier types. It

also lists various readiness conditions under which the carriers must sustain operations. In meeting these conditions, there is no differentiation between conventional and nuclear carriers.

Neither is there any differentiation in carrier types in setting requirements for overseas presence or in allocating assets to achieve presence objectives. The Joint Chiefs of Staff-approved Global Naval Force Presence Policy, for example, states the requirements for carrier presence in terms of the number of carriers allocated to each theater without specifying the type of carrier.

Similarly, the guidance various headquarters and commands provide on transit speed, escorts, and fuel and ordnance loads does not differentiate between carrier types. The guidance we reviewed specifies the same maximum transit speeds for all carriers and requires that one or more surface combatants, such as a cruiser or a destroyer, are necessary at all times to escort and protect the aircraft carrier irrespective of propulsion type. The guidance also states that all ships will replenish their supplies after reaching a specified minimum level, which is the same for both conventional and nuclear carriers.

The operational planning process for wartime does not distinguish between the two propulsion types. Joint Staff officials said that a carrier's type of propulsion is virtually transparent at their level. The Joint Staff apportions carriers to the unified commanders irrespective of propulsion type, and regional commanders prepare their operational plans based on the expectation that they will receive this specified number of carriers if the plans are executed. With the current mixed fleet of nuclear and conventional carriers, the specific carriers that will respond if the plans are executed will depend on the availability and readiness status of the individual carriers at that time.

Conventionally and Nuclear-Powered Carriers Employ a Standard Air Wing

The Navy's Policy for Carrier Battle Groups prescribes a standard composition for the air wings assigned to aircraft carriers. The standard composition is the same for both conventionally powered and nuclear-powered aircraft carriers.¹⁷ The composition of an air wing is shown in table 2.5.

Table 2.5: Composition of a Standard Carrier Air Wing

Aircraft	Mission	Number of aircraft
F-14	Strike/fighter	14
F/A-18	Strike/fighter	36
E-2C	Airborne early warning	4
EA-6B	Suppression of enemy air defense/electronic warfare	4
S-3B	Antisubmarine warfare/anti-surface ship warfare/air refueling	8 ^a
ES-3A	Electronics intelligence	2
H-60	Antisubmarine warfare/search and rescue/utility	6
Total		74

^aThe S-3 is normally used to refuel the wing's other aircraft during the launch/recovery process. However, it is not well-suited for refueling the other aircraft on long-range missions. On those missions, the air wing's aircraft frequently refuel from Air Force tanker aircraft such as the KC-135 and the KC-10.

We examined the air wing composition of five carrier deployments (three conventional and two nuclear) and found that both carrier types deployed with only minor variations in the number of aircraft prescribed in the policy. Some deployments that included both carrier types carried one to three more support aircraft than the standard wing.

With the embarked standard air wing, the two types of carriers are expected to generate the same number of sorties per day. During a crisis, a carrier may be tasked to fly more than the normal number of sorties or "surge" operations. The Battle Group Policy states that for augmented

¹⁷As noted in chapter 1, the aircraft carrier "maximum density" is the same for both the U.S.S. John F. Kennedy (CV-67) and Nimitz-class (CVN-68) carriers. An aircraft carrier's capacity for carrying aircraft is expressed as aircraft carrier maximum density, a comparative number of F/A-18 equivalents that can be carried aboard a ship. Maximum density takes into account the space on the hanger and flight decks that the aircraft and helicopters in the air wing need as well as space for other items such as boats, boat skids, aircraft ground support equipment, forklifts, cranes, and aircraft jacks. It also allows for the clearances needed between the aircraft and between the aircraft and ship structures. The Navy's guidance on aircraft carrier density states that 75-78 percent of maximum density is the optimum number of aircraft to have aboard and that deck loading in excess of 80 percent must be coordinated with headquarters. Ship officials said that about 47-50 aircraft on the flight deck at any one time provides the flexibility to conduct flight operations and move aircraft on the flight deck and between the flight deck and hangar bay.

operations (during which an additional 12 strike-fighter aircraft would be assigned to the carrier), carriers must be able to generate 170 sorties per day during the initial crises response, 140 sorties per day for 3 to 5 days, and 90 sorties per day thereafter for sustained operations.

Both types of carriers are subject to the same limitations of crew fatigue (both aircrew and ship's company) and equipment maintenance, which could affect sortie generation. For example, Navy regulations limit how much flight personnel can fly and mandate rest periods. Officials told us that deck crews and ordnance personnel would also be stressed during periods of increased sortie generation. Additionally, both types of carriers have the same catapult and arresting gear equipment that is subject to a strict inspection and maintenance schedule. These factors can limit a carrier's ability to generate sorties before aviation fuel and ordnance levels are depleted. As a result, the type of propulsion does not affect the length of time either carrier type could sustain periods of increased sortie generation.

Top Speeds Are Similar

The two types of carriers have similar top speeds—in excess of 30 knots. Additionally, neither type has any unique, propulsion-related constraints to maintaining speeds at that level for extended periods. One difference when sailing at high speeds is the conventional carrier's need to slow for underway refueling. However, as discussed earlier, the impact is minimal.

According to Navy and shipyard officials, the method used to generate steam does not determine a carrier's top speed. Factors such as shaft horsepower, shaft torque limits, propeller design, displacement, and the naval architectural characteristics of the hull are the determinates of speed.

Defense and Navy officials also said that other restraints preclude routinely sailing at high speeds for extended periods. Air crews have to fly periodically during a transit to remain qualified. Because a carrier would be unable to conduct flight operations during a 30-knot plus sustained voyage, the air crews would have to spend several days after arrival at the destination requalifying before they could be operationally employed.¹⁸ Officials at one of the unified commands said that they would prefer to have a carrier battle group with trained crews arrive in their theater later than have one with an air wing that needed to requalify arrive earlier.

¹⁸At high transit speeds, a carrier may not be able to maneuver as necessary to conduct flight operations.

High sea states and inclement weather could also preclude sustained, high speed voyages. A ship cannot sail fast in heavy weather without punishing the ship and its crew, regardless of its type of propulsion. Additionally, while the escorts in the battle group are generally capable of speeds in excess of 30 knots, they experience greater difficulty than carriers sustaining high speeds in very rough sea conditions. Also, as a Navy official pointed out, even at 30 knots, a long transit from the West Coast to the Central Command's area of responsibility would still take about 2 weeks.

Propulsion Type Does Not Materially Affect Carrier Survivability

To successfully attack and degrade a U.S. aircraft carrier's ability to perform its mission, an enemy must detect the carrier and fix its location with sufficient accuracy so that one or more weapons can strike it. Additionally, the lethality of the attacking weapon(s) must be of sufficient magnitude to severely damage or sink the carrier. Officials of the Naval Sea Systems Command told us, according to their survivability analyses, neither type of carrier possesses any inherent, overriding advantage over the other in its susceptibility to detection or its vulnerability to the damage inflicted by the weapons.¹⁹ They also said that the two types of carriers are very similar in construction, were built to the same shock standards, and use similar machinery and equipment. Thus, while there are some differences, neither has a distinct advantage withstanding or recovering from the effects of enemy weapons that can be attributed specifically to the ship's propulsion type.²⁰

Naval Sea Systems Command officials believe that the nuclear carrier's speed and unlimited range give it a distinct operational advantage, but they also told us that there were no analytical studies addressing these operational factors to support this belief. They said that these attributes allow a nuclear-powered carrier to employ tactics that minimize the risk of detection, thus reducing its overall susceptibility to attack. Additionally, a conventional carrier must be periodically refueled with propulsion fuel. Thus, it is susceptible to attack while alongside an oiler because it is

¹⁹DOD defines survivability as the capability of a system and crew to avoid or withstand a man-made hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission. Susceptibility is the degree to which a weapon system is open to effective attack due to one or more inherent weakness (a function of operational tactics, countermeasures, probability of enemy fielding a threat, etc.). Vulnerability is the characteristic of a system that causes it to suffer a definite degradation as a result of having been subjected to a certain level of effects in an unnatural hostile environment. Both susceptibility and vulnerability are considered to be subsets of survivability.

²⁰The officials said that, while the more recent nuclear carriers have been built with enhanced magazine protection, this same level of protection could be incorporated in newly constructed conventional carriers.

steaming a steady course at a steady speed. A nuclear carrier is not as exposed to this susceptibility because it does not have to replenish its propulsion fuel.

Both types of carriers, however, must periodically replenish their supply of aviation fuel. Since carriers normally replenish all supplies and fuel during an underway replenishment, a conventional carrier normally takes on ship propulsion fuel (DFM) and JP-5 simultaneously. However, the nuclear carrier still retains an advantage because, with its greater JP-5 capacity, it does not have to refuel as often.²¹ Additionally, while refueling does restrict a carrier's ability to maneuver, the carrier typically moves to the rear to be less exposed when replenishing fuel, ammunition, and other supplies. That operation takes place under the defensive umbrella of the surface combatants of the battle group.

Fresh Water Production Capabilities Are Similar

An adequate fresh water supply is critical to both types of ships. The steam that drives the turbines that propel the carriers through the water and powers the catapults that launch the aircraft is produced from fresh water. Fresh water is also used to cool equipment, for damage control, and to wash aircraft and the flight deck.²² Both types of carriers need to retain fresh water reserves. About half of a nuclear carrier's fresh water storage capacity is for use as emergency reactor coolant. Finally, there is the requirement for "hotel services," the water the crew uses daily for preparing meals, drinking, laundry, and personal hygiene. According to Newport News Shipbuilding officials, both types of carriers have essentially the same water requirements.

Some of the older conventional carriers produce about 20,000 gallons a day less than the Nimitz-class, which can produce about 400,000 gallons per day. However, the U.S.S. Kennedy (CV-67) can produce 50,000 gallons a day more than the Nimitz-class. Navy officials said that any differences in fresh water production between conventional and nuclear carriers may be due to the conventional carriers' age. Newport News Shipbuilding officials also said that the differences are due to increases in the number of aircraft and personnel, not to differences in the propulsion type.

²¹During Operation Desert Storm, the conventionally powered carriers in the Persian Gulf replenished aviation fuel about every 2.7 to 3 days. The U.S.S. Roosevelt, the only nuclear-powered carrier in the Desert Storm air campaign also operating in the Persian Gulf, replenished its aviation fuel about every 3.3 days.

²²Some Navy officials told us that conventional carriers use more fresh water to wash their aircraft to remove the boiler stack gas residue.

Some Navy officials said that in harsh environments such as the Persian Gulf, conventional carriers frequently resort to water rationing to provide for essential services. Our review showed that the conventional carriers' ability to produce fresh water is similar to that of nuclear carriers and that rationing does not occur that frequently.

Other Navy officials we met with discounted the problem of rationing aboard conventional carriers. They believe that fresh water shortages are, in many instances, indicative of management problems or inefficiencies aboard the ship—leaking boilers or pipes, for example. Some officials stated that, during their service, they had experienced water rationing as frequently, if not more frequently, aboard nuclear carriers as they had aboard conventional carriers. Officials, who had recently served aboard three conventional carriers in the Persian Gulf said that the ships had experienced no water rationing.

Nuclear Carriers' Design Affords Greater Ordnance and Aviation Fuel Storage Capacity

The design of nuclear carriers has provided greater aviation fuel and ordnance storage capacity than conventional carriers, while their propulsion system has provided almost unlimited steaming endurance. Together, these factors could give nuclear carriers a decided operational advantage and superior war-fighting capability over their conventional counterparts if no at-sea logistics support were present. In reality, however, at-sea logistics support is present, and both carrier types and their surface escorts depend on this support to sustain operations.

The Larger Storage Capacity of Nuclear Carriers Is Due Primarily to Ship Design

The larger fuel and ordnance storage capacities of the nuclear carrier are primarily due to ship design differences that have little to do with the type of propulsion and the fact that nuclear carriers do not have to store large amounts of propulsion fuel. A ship's length, height, and width determine its internal volume, and as a result, the amount of fuel and ordnance that can be carried. Due to its larger hull size, the Nimitz-class nuclear aircraft carrier is about 10 percent larger than the last conventional carrier.²³ According to officials at Newport News Shipbuilding, the hull size of the nuclear carrier was more to provide increased space for ordnance, aviation fuel, and other supplies.

²³The conventional carrier U.S.S. Kennedy (CV-67) has about 75 percent of the storage capacity of the first three nuclear ships of the Nimitz-class and about 80 percent of that of the U.S.S. Roosevelt (CVN-71) and the latter ships of the Nimitz-class. These latter ships have less storage space due to the addition of enhanced overhead and side protection that earlier Nimitz-class carriers lacked.

The debate that took place when the Navy was originally considering building more nuclear aircraft carriers, in addition to the U.S.S. Enterprise (CVN-65), illustrates this point. For example, Admiral Rickover, in a 1964 letter to the Secretary of the Navy arguing that CV-67 be nuclear-powered, cited advantages of the Enterprise.²⁴ The letter states that the Enterprise hull is 50 feet longer than the CV-67's hull, which provides the 60-percent increase in ammunition storage. It also states the "... conventional carrier could also be built in an Enterprise size hull. This would provide an equivalent increase in the ammunition in the conventional carrier and would also provide a[n] ... small increase (about 15%) in aviation fuel."

Additionally, a 1992 Center for Naval Analyses research memorandum documenting the feasibility of five alternative aircraft carrier concepts developed by the Naval Sea Systems Command stated that, other than endurance range, a carrier built with a Nimitz-type hull but powered by a Kennedy-type oil-fired steam plant would be essentially equivalent to the Nimitz-class design. With enough propulsion fuel for a range of 8,000 nautical miles—a distance equal to about one-third the way around the world—at 20 knots (the equivalent of the current conventional carriers), the conventional variant would have the same magazine and aviation fuel (JP-5) capacities as today's CVN-68 class.

At-Sea Replenishment Offsets the Conventional Carrier's More Limited Storage Capacity and Endurance

While nuclear carriers can operate for years before requiring propulsion fuel, they have a finite storage capacity for aviation fuel, ordnance, and other supplies. In addition, they are escorted by conventionally powered escorts, such as cruisers and destroyers, that require underway support due to their smaller fuel capacities and relatively high rate of fuel consumption. All surface combatant ships are highly dependent on regular resupply at sea.

The Navy operates a Combat Logistics Force fleet of about 40 ships that resupply combatant ships at sea with ship and aircraft fuel, ordnance, food, and other supplies. The Combat Logistics Force enables combatant ships to operate at sea almost indefinitely, if required, without returning to port to replenish their stocks. The Combat Logistics Force consists of two basic types of ships—station ships and shuttle ships. Station ships, such as the AOE multipurpose fast combat support ship, are an integral element of carrier battle groups, routinely resupplying the other ships in the group.

²⁴Admiral Rickover prepared the letter in his capacity as the Manager of Navy Reactors at the Atomic Energy Commission.

AOEs can simultaneously deliver fuel, ordnance, and other supplies.²⁵ The station ships provide the initial logistic support in theater until shuttle ships, such as fleet oilers and ammunition and other supply ships, can catch up. According to Navy logistics doctrine, station ships support a typical battle group with fuel for 20-30 days, consumables (other than fuel and ordnance) for 75 days, and spare parts for 90 days.

The station ships, in turn, are generally replenished by ships that shuttle from forward naval bases to the battle group. At times, these single-product shuttle ships also replenish the combatant ships directly. The Combat Logistics Force represents additional days of sustainability for the naval force by serving as an extension of the combatant ships' bunkers, magazines and store rooms. See appendixes III and V for a more-detailed discussion of the impact of the Combat Logistics Force on carrier battle group operations.

We compared the endurance of a notional conventional carrier battle group to a nuclear carrier battle group using Navy fuel and ordnance consumption rates contained in a 1993 Center for Naval Analyses report.²⁶ The notional battle groups we used consisted of either a conventional or nuclear carrier, plus two Ticonderoga-class Aegis guided missile cruisers (CG-47/52s), two Spruance-class destroyers (DD-963s), and two Arleigh Burke-class Aegis guided missile destroyers (DDG-51s). Each battle group was supported by one Sacramento-class supply ship (AOE-1). We estimated that the conventional battle group would have enough (1) fuel to steam for 29 days, (2) aviation fuel to operate at a tempo comparable to the final days of Desert Storm for 17 days, and (3) aircraft ordnance for 30 days. The conventional escorts of the nuclear carrier battle group would have enough fuel to steam for 34 days, while the nuclear carrier would have enough (1) aviation fuel to operate at a tempo comparable to the final days of Desert Storm for 23 days and (2) ordnance to operate for 41 days.

²⁵The multipurpose fast combat supply ship (AOE) is the only noncombatant ship in the battle group and has the speed to keep up with the other ships. The Navy currently has four Sacramento-class (AOE-1) ships, and three slightly smaller Supply-class (AOE-6) ships, with one more being built. When an AOE is not available, a combination of ships can be used to carry out its role, such as oilers (AO) and ammunition ships (AE). However, these other types of ships do not carry the range of products that an AOE carries and, since their top speeds are about 20 knots, they do not have the speed to keep up with the other ships in the battle group.

²⁶Center for Naval Analyses Report 205, "Sizing the Combat Logistic Force," June 1993. The Center used 1990 and 1991 fleet data contained in the Navy Energy Usage Reporting System (NEURS) for fuel consumption and aircraft fuel and ordnance consumption based on the final days of Desert Storm.

Nuclear Carriers Have a Greater Acceleration Capability

Navy officials said that a nuclear carrier would be better able to recover landing aircraft if wind and weather conditions suddenly changed or if the aircraft experienced mechanical difficulties, since it could accelerate more quickly than a conventional carrier to generate the additional “wind over deck” needed to safely land an aircraft.²⁷ The officials said that, under such conditions, a nuclear carrier can accelerate much quicker than a conventional carrier can because its reactors are always “on line.” According to Navy data, a nuclear carrier needs about 1-1/2 minutes to accelerate from 10 to 20 knots and about 3 minutes to accelerate from 10 to 30 knots. On the other hand, a conventional carrier steaming with four boilers on line producing steam can accelerate from 10 to 20 knots in about 2-1/2 minutes to 5 minutes. However, it cannot achieve 30 knots with four boilers—all eight boilers are needed.²⁸ If its eight boilers are on line, it needs as little as 12-1/2 minutes to accelerate from 10 to 30 knots. However, according to Navy officials, it can take as long as 1-1/2 to 2 hours to place boilers that are in a standby condition into full operation.

According to fleet and ship officials, additional factors, such as preparing the flight deck, may affect the recovery of aircraft. They said that a ship’s crew is aware of wind conditions during flight operations and, on a conventional carrier, they will normally have enough boilers on line so that the carrier can respond in a timely manner to recover landing aircraft. In addition, aerial tankers are always airborne during aircraft recovery to ensure that planes do not run low on fuel while waiting to land. Officials also noted that on a light wind day, both conventional and nuclear carriers may restrict flight operations rather than risk a situation where not enough wind over deck could be generated.

Our review of Naval Safety Center data concerning carrier landings and Class A mishaps indicated that landing accidents of that magnitude are rare.²⁹ The Center identified 10 carrier-related landing mishaps from 1986 through 1996 (6 aboard conventional carriers and 4 aboard nuclear carriers). During that time period, there were about 545,000 and 470,000 landings aboard conventional and nuclear carriers, respectively. One

²⁷The “wind over deck” is the sum of a carrier’s speed and natural wind speed. Carrier aircraft have a minimum required “wind over deck” to safely land aboard a carrier. The “wind over deck” required varies by aircraft type and condition. A Navy official said that an F-14, for example, needs about 25 knots wind across the deck. There are some instances that would require natural wind in excess of 10 knots, even if the carrier was steaming at its top speed.

²⁸For example, the Kennedy’s top speed, with four boilers on line, is about 26 knots.

²⁹DOD defines a Class A flight mishap as one involving a DOD aircraft with an intent to fly, which resulted in damages totaling \$1 million or more, a destroyed aircraft, a fatality, or a permanent total disability.

Center official and fleet officials told us that the flight deck's layout plays a greater role in safety than does the ship's ability to accelerate. Such design features are not related to the ship's type of propulsion.

Navy officials could not provide us examples of aircraft being lost because a conventional carrier could not accelerate fast enough. Additionally, a Naval Safety Center official told us that the Center had no record of an aircraft crashing because a carrier could not increase its speed quickly enough.

Agency Comments and Our Evaluation

DOD believed the draft report did not adequately address operational effectiveness features provided by nuclear power. According to DOD, any analysis of platform effectiveness should include mission, threat, and capabilities desired over the life of the ship. Further, it stated the draft report did not adequately address future requirements but relied on historical data and did not account for platform characteristics unrelated to propulsion type. That is, many of the differences may be explained by platform size, age, and onboard systems than by the type of propulsion.

The Congress asked us to examine the cost-effectiveness of conventionally and nuclear-powered aircraft carrier propulsion. Such an analysis seeks to find the least costly alternative for achieving a given requirement. In this context, we used as the requirement DOD's national military strategy, which is intended to respond to threats against U.S. interests. That strategy encompasses overseas peacetime presence, crises response, and war-fighting capabilities. We used those objectives as the baseline of our analysis and selected several measures to compare the effectiveness of conventionally and nuclear-powered carriers. Those measures were discussed with numerous DOD, Joint Staff, and Navy officials at the outset. Those measures reflect the relative capabilities of each propulsion type, including the nuclear-powered carrier's greater aviation fuel and munitions capacity and unlimited range. Notwithstanding the enhanced capabilities of nuclear propulsion, we found that both types of carriers share many of the same characteristics and capabilities, that they are employed interchangeably, and that each carrier type possesses certain advantages. We also found that both types of carriers have demonstrated that each can meet the requirements of the national military strategy.

We believe our methodology of reviewing a historical perspective covering a wide range of peacetime presence, crises response, and war-fighting scenarios that both types of carriers faced during the past 20 years is

sound. A full discussion of our methodology can be found in appendix I. We continue to believe that this assessment will be helpful to the Navy as it assesses design concepts for a new class of aircraft carriers.

Life-Cycle Costs for Nuclear-Powered Aircraft Carriers Are Greater Than for Conventionally Powered Carriers

A nuclear-powered carrier costs about \$8.1 billion, or about 58 percent, more than a conventionally powered carrier to acquire, operate and support for 50 years, and then to inactivate. The investment cost for a nuclear-powered carrier is more than \$6.4 billion, which we estimate is more than double that for a conventionally powered carrier. Annually, the costs to operate and support a nuclear carrier are almost 34 percent higher than those to operate and support a conventional carrier. In addition, it will cost the Navy considerably more to inactivate and dispose of a nuclear carrier (CVN) than a conventional carrier (CV) primarily because the extensive work necessary to remove spent nuclear fuel from the reactor plant and remove and dispose of the radiologically contaminated reactor plant and other system components. (See table 3.1.)

Table 3.1: Life-Cycle Costs for Conventional and Nuclear Aircraft Carriers (based on a 50-year service life)

Fiscal year 1997 dollars in millions		
Cost category	CV	CVN
Investment cost^a		
Ship acquisition cost	\$2,050	\$4,059
Midlife modernization cost	866	2,382
Total investment cost	\$2,916	\$6,441
Average annual investment cost	\$58	\$129
Operating and support cost		
Direct operating and support cost	\$10,436	\$11,677
Indirect operating and support cost	688	3,205
Total operating and support cost	\$11,125	\$14,882
Average annual operating and support cost	\$222	\$298
Inactivation/disposal cost		
Inactivation/disposal cost	\$53	\$887
Spent nuclear fuel storage cost	n/a	13
Total inactivation/disposal cost	\$53	\$899
Average annual inactivation/disposal cost	\$1	\$18
Total life-cycle cost	\$14,094	\$22,222
Average annual life-cycle cost	\$282	\$444

Note: Numbers may not add due to rounding.

^aCVN investment cost includes all nuclear fuel cost; CV fuel is included in operations and support activities.

Source: Our analysis of Navy data.

What Is a Life-Cycle Cost Analysis?

One of the most persistent challenges facing DOD is the ability to provide adequate resources for the acquisition, operations, and support of its systems and equipment. A life-cycle cost analysis provides managers with important information for a number of purposes, including improved long-range planning and budgeting, decisions about replacing aging equipment, and comparisons of competing programs and systems. A keystone to sound acquisition decisions is having an estimate of the total cost of a program or equipment over its full life (i.e., life-cycle cost). For this reason, a life-cycle cost analysis has been part of the DOD acquisition system for many years.

The life-cycle cost is the sum total of direct, indirect, recurring, and nonrecurring costs of a system over its entire life through its disposal. The important point is that the total cost is not just the initial near term cost. Typically, a life-cycle cost analyst will focus attention on the annual operating and support cost because it usually accounts for the largest share of the total cost. The most common cost components that are included in a life-cycle cost analysis are shown in figure 3.1.

Figure 3.1: Life-Cycle Cost Components

Operations and Support	Operations and Support	Disposal
Research and development	Direct costs	Inactivation
Ship acquisition	--Personnel	Disposal
Military construction	--Depot maintenance	
	--Fuel	
	Indirect costs	
	--Training	
	--Technical services	
	--Logistics support	

Source: GAO.

We developed a life-cycle cost model to estimate the life-cycle cost for a nuclear- and a conventionally powered aircraft carrier. We used the Nimitz-class carrier as our baseline for the nuclear carrier. We selected the

Kennedy-class¹ as the baseline for a conventional carrier because it is comparable in size to the Nimitz-class carrier, it can employ an air wing that is similar to that on a Nimitz-class carrier, and there was adequate historical cost data available to build our cost estimates. Detailed information about the methodologies we used to develop our cost estimates is discussed in this chapter and appendix I.

Investment Costs Are
Higher for
Nuclear-Powered
Carriers Than for
Conventionally
Powered Carriers

Ship acquisition and midlife modernization costs for a nuclear-powered carrier are double that estimated for a conventionally powered carrier. (See table 3.2.)

Table 3.2: Investment Costs for
Conventional and Nuclear Aircraft
Carriers

Fiscal year 1997 dollars in millions		
Investment category	CV	CVN
Ship acquisition	\$2,050	\$4,059
Midlife modernization	866	2,382
Total	\$2,916	\$6,441

Note: Numbers may not add due to rounding.

Source: Our analysis of Navy data.

Acquisition Cost

Historically, nuclear carriers have cost more to acquire than conventional carriers, for several reasons. First, they are larger and heavier than conventional carriers. Second, the acquisition cost for a nuclear carrier includes nuclear fuel cost. Finally, the unique industrial base, specialized nuclear suppliers, and the Naval Nuclear Propulsion Program's exacting and stringent environmental, health, and safety standards add to this cost. For example, an unavoidably high cost overhead structure (engineering, quality assurance, and production control) and costly production work are required in the naval nuclear propulsion industry. Shipbuilders must

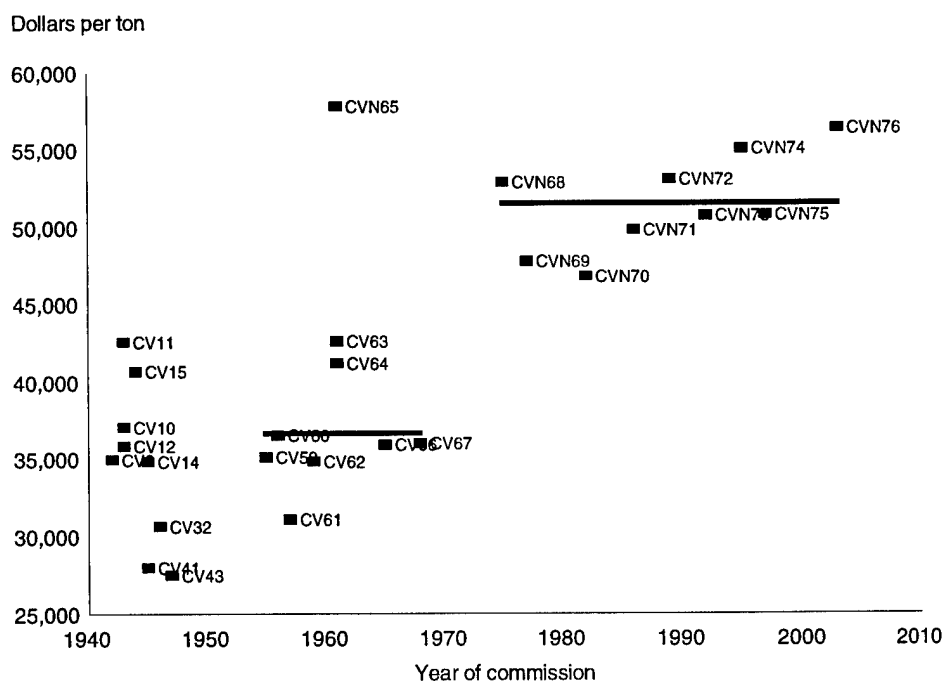
¹For our analysis, the Kennedy-class includes the CV-63, CV-64, CV-66, and CV-67 as these carriers are similar in size, displacement, crew size, and maintenance plans, and are often grouped together.

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follow “non-deviation” plans (i.e., no deviation from the approved plans without government approval).

We obtained acquisition cost data for 27 carriers that were authorized or built since 1942. Figure 3.2 shows, in constant dollars, the acquisition cost per ton² of conventionally and nuclear-powered carriers. Acquisition costs for the Nimitz-class nuclear-powered carriers have averaged about \$3.9 billion³ while the last conventionally powered carrier, the U.S.S. John F. Kennedy (CV-67), cost \$2.1 billion. Regardless of the year the ship was commissioned, nuclear carriers cost more than conventional carriers.

Figure 3.2: Acquisition Cost per Ton for Conventional and Nuclear Carrier (fiscal year 1997 dollars)



Source: Navy.

²To allow for increases in both ship weight and cost, the acquisition cost per ton is produced by dividing the ship's acquisition cost by its tonnage. We used the ship's light displacement tonnage that did not include weight due to the ship's fuel, water, or ammunition.

³Includes nuclear fuel cost.

The acquisition costs of about \$2.1 billion for the conventional carrier and \$4.1 billion for the nuclear carrier were based on an estimating methodology similar to one used by us in an earlier study⁴ and by the Center for Naval Analyses. Historical acquisition cost per ton and the ship's displacement tonnage were used to provide rough order of magnitude estimates for the acquisition costs of a Kennedy-class and a Nimitz-class ship. (See table 3.3 and app. I for a detailed discussion of the methodology.)

**Table 3.3: Acquisition Cost Estimates
for the Conventionally and
Nuclear-Powered Carrier**

Fiscal year 1997 dollars

	Cost per ton ^a	Ship displacement ^b	Estimated cost
CV	\$35,191	58,268	\$2,050,500,000
CVN	\$51,549	78,741	\$4,059,000,000

Note: Numbers may not add due to rounding.

^aWe determined the ratio between the cost per ton of CV-67 and CVN-68 (less any nuclear fuel related cost) and applied this ratio to the average cost per ton for the CVN-68 class to estimate the cost per ton for a newly acquired conventional carrier. We used the average cost per ton for the CVN-68 class as the estimated cost per ton for the nuclear carrier.

^bDisplacement as measured in light tons.

Source: Our analysis of Navy data.

Midlife Modernization

Our analysis shows that it will cost the Navy nearly three times as much to refuel, overhaul, and modernize a nuclear carrier than it will a conventional carrier. Both carrier types require some level of midlife modernization to allow the Navy to use the ships for nearly 50 years. When a nuclear carrier has been in service for nearly 24 years,⁵ it will undergo a 2-1/2 year refueling complex overhaul (RCOH), which includes refueling the reactor plant, repairing the propulsion plant, restoring the ship's material condition, and performing modernization efforts. The nuclear carrier is expected to operate another 24 years after the RCOH. Similarly, at about age 30, a conventional carrier can undergo a 2-1/2 year Service Life Extension Program (SLEP) which includes restoring the ship's condition, installing system upgrades and performing modernization efforts. After a SLEP, the conventional carrier should operate an additional 15 years or

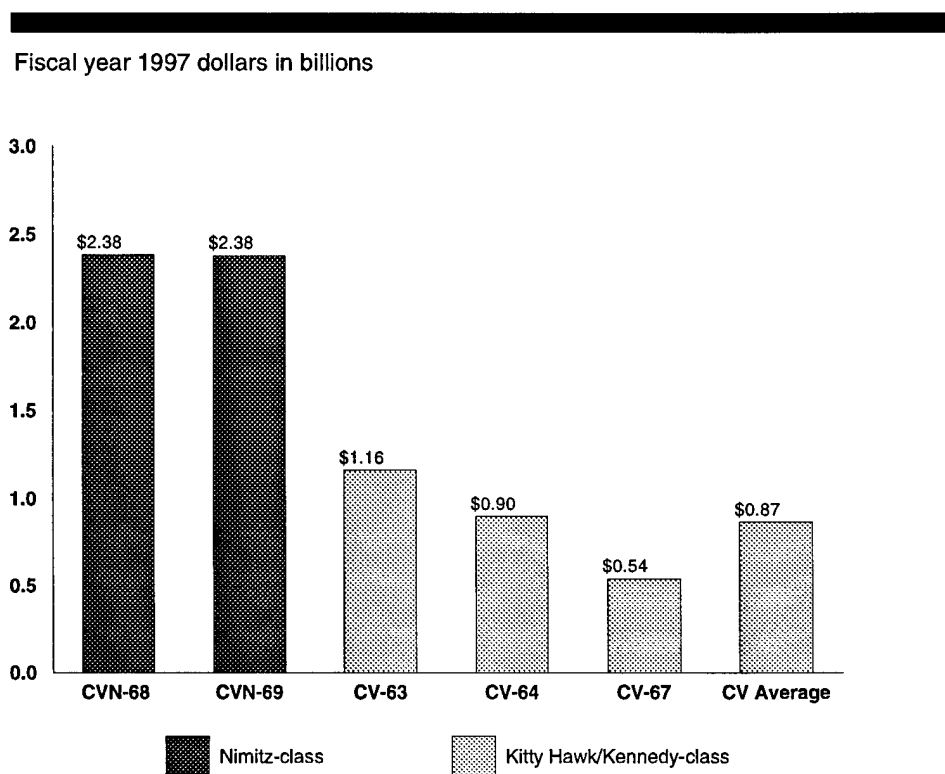
⁴Navy's Aircraft Carrier Program: Investment Strategy Options (GAO/NSIAD-95-17, Jan. 1995).

⁵Given current operating tempo, its nuclear fuel is expected to last about 24 years before it needs to be replaced. Midlife modernization will take place at the time of refueling.

more. In both cases, the actual work required for midlife modernization will vary for each individual ship, depending on the ship's condition.

Figure 3.3 shows the estimated RCOH cost for the first two Nimitz-class carriers and the actual cost for SLEPs performed on the Kennedy-class⁶ conventional carriers. We used the Navy's best estimate for the RCOH planned for the CVN-68 as the estimated midlife modernization cost for the nuclear carrier. For our cost model, we used the average historical cost for SLEPs performed on the Kennedy-class conventional carriers as the estimated midlife modernization cost for the conventional carrier.

Figure 3.3: Midlife Modernization Cost for CVN-68, CVN-69 and Kennedy-class Conventional Carriers



Note: We used estimated cost for nuclear carriers and actual cost for the conventional carriers.

Source: Navy.

⁶The CV-66 did not undergo a SLEP.

Nuclear Carriers Are More Expensive to Operate and Support Than Conventional Carriers

We estimate that it will cost about \$14.9 billion to operate and support a nuclear carrier over its lifetime, which is nearly 34 percent more than the \$11.1 billion we estimate it will cost to operate and support a conventional carrier. As shown in table 3.4, the cost for a conventionally powered carrier's fossil fuel is more than offset by the added cost for a nuclear-powered carrier's personnel and depot maintenance. A major cost difference between the two carrier types is in the indirect cost category for support activities provided by DOE to the nuclear carriers.

Table 3.4: Life-Cycle Direct and Indirect Operating and Support Costs for a Conventionally and Nuclear-Powered Carrier

Fiscal year 1997 dollars in millions		
Cost category	CV	CVN
Direct operating and support costs		
Personnel	\$4,636	\$5,206
Fossil fuel	738	n/a
Depot maintenance ^a	4,130	5,746
Other ^b	933	724
Total direct operating and support costs	\$10,436	\$11,677
Indirect operating and support costs		
Training	\$161	\$1,107
Fossil fuel delivery	469	n/a
Nuclear support activities	n/a	2,045
Other ^c	58	53
Total indirect operating and support costs	\$688	\$3,205
Total operating and support costs	\$11,125	\$14,882

Note: Numbers may not add due to rounding.

^aIncludes routine maintenance, repairs, and ship modernization work but not the cost of midlife modernization.

^bIncludes a number of direct unit cost categories such as spare parts, supplies, and intermediate maintenance.

^cIncludes a number of indirect support cost categories such as publications, ammunition handling, and technical services.

Source: Our analysis of Navy data.

Direct Operation and Support Costs

Nuclear carriers have higher personnel costs than conventional carriers primarily because they require additional personnel and their nuclear personnel receive special pay and bonuses. Depot maintenance costs are greater for a nuclear carrier because more labor is needed to maintain it

than is needed for a conventional carrier. In a separate analysis, we found that the total cost related to nuclear fuel over a nuclear carrier's lifetime exceeded the lifetime cost for a conventional carrier's fossil fuel. We did not review the reasons for the cost differences for other elements in the direct cost category because it included costs from a number of subcategories such as travel, spare parts, and intermediate maintenance. In most cases, the cost difference for each individual subcategory was not significant enough to warrant detailed review.

Personnel Costs

The personnel cost for a nuclear carrier is estimated at about \$5.2 billion over its lifetime compared to about \$4.6 billion for a conventional carrier (see table 3.5). Our estimated personnel cost is based on historical personnel cost reported by the Navy's Visibility and Management of Operating and Support Cost (VAMOSOC) Management Information System database for the CV-67 class and CVN-68 class carriers as well as an additional 30.6 percent to account for accrued retirement cost, which is not captured by that database.

Table 3.5: Personnel Costs for
Conventionally and Nuclear-Powered
Carriers

Fiscal year 1997 dollars in millions		
	CV	CVN
Annual personnel cost	\$71	\$80
Annual accrued retirement	22	24
Total annual	\$93	\$104
Life-cycle cost	\$4,636	\$5,206

Note: Numbers may not add due to rounding.

Source: Our analysis of Navy data.

To determine why the nuclear-powered carrier's personnel cost is higher, we analyzed ship manpower documents. On the basis of our work, we are reasonably certain that most of the cost difference can be attributed to the different propulsion plants and not some other ship characteristic. Our work further indicates that the higher cost are the result of three factors: increased personnel needed to operate the nuclear propulsion plant, higher grade structure for propulsion plant personnel and bonuses, and special duty pay for nuclear personnel.

A nuclear carrier has a requirement for nearly 3,400 personnel compared to about 3,200 for a conventional carrier. A majority of the added personnel can be traced to the departments that operate the propulsion

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plant.⁷ Table 3.6 provides a comparative summary of the required propulsion plant personnel for nuclear and conventional carriers.

Table 3.6: Propulsion Plant Personnel for Conventional and Nuclear Carriers

Personnel	CV	CVN	Difference
Officers ^a	22	33	11
Enlisted	597	716	119
Total	619	749	130

^aIncludes warrant officers.

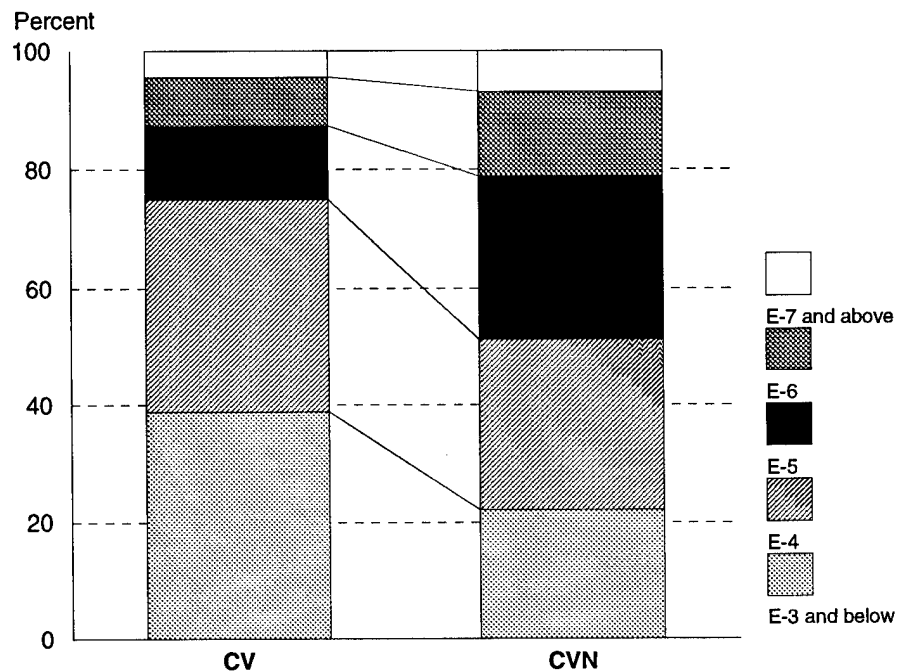
Source: Navy.

Some of the higher personnel cost for the nuclear carrier can be attributed to the grade structure of propulsion plant personnel. Nuclear propulsion plant personnel are a higher grade level than propulsion plant personnel for a conventional carrier. As shown in figure 3.4, nearly 50 percent of a nuclear carrier's enlisted propulsion plant personnel are E-5 and above whereas 75 percent of a conventional carrier's propulsion personnel are E-4 and below.

⁷This includes the Engineering Department for the conventionally powered carrier and the combination of the Engineering and Reactor Departments for the nuclear-powered carrier.

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Figure 3.4: Grade Structure for the
Enlisted Propulsion Plant Personnel
for Conventionally and
Nuclear-Powered Carriers



Source: Our analysis of Navy data.

The higher personnel cost for a nuclear carrier can also be attributed to special pay and bonuses. The Navy uses a variety of incentive pay and bonuses to attract and retain nuclear personnel (see table 3.7).

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**Table 3.7: Special Pay and Bonus
Incentives Available for Nuclear
Personnel in Fiscal Year 1997**

Enlisted	
Enlistment bonus	Up to \$4,000
Selective reenlistment bonus	Up to \$30,000 ^a
Special duty assignment pay	Up to \$275 per month ^b
Officers	
Accession bonus	Up to \$8,000
Annual incentive	Up to \$12,000 ^c

^aVariable bonus based on award level. Nominal bonus of \$22,000 for a 6-year reenlistment of an E-5 with 24 months in service.

^b An E-5 would receive \$150 per month.

^cVariable bonus based on active duty commitment length.

Source: Navy.

Fuel Costs

We estimate it costs \$738 million to provide fossil fuel over a conventional carrier's 50-year life. Historical data indicate that a conventional carrier uses about 500,000 barrels of fossil fuel each year or about 25 million barrels over its lifetime. Our estimate was developed by multiplying the estimated barrels of fuel consumed by \$29.52, which was the average per barrel price the Navy paid for fossil fuel from fiscal year 1991-95. Because of historical interest and speculation as to escalation in fossil fuel prices, we examined trends in fossil fuel prices and performed a sensitivity analysis of a conventional carrier's life-cycle cost if fuel prices were to double (see app. I).

The fuel cost for a conventional carrier is clearly visible as an operating and support cost. Conversely, the fuel cost for a nuclear carrier is included within the investment cost (e.g., acquisition, midlife modernization) and, therefore, is not clearly identified. We compared the costs of fossil and nuclear fuel and found that the life-cycle cost for nuclear fuel is greater than for fossil fuel.

Given current operating tempo, the nuclear fuel cores for the Nimitz-class carrier are expected to provide enough power for about 24 years. When the initial fuel cores are depleted, the cores are removed and replacement fuel cores are installed. Replacement cores will be removed when the ship is inactivated at the end of its service life. To provide a comparison of fuel cost, the Navy identified portions of the investment costs that directly relate to the initial and replacement cores (see table 3.8).

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Table 3.8: Nuclear Fuel Cost for a Nimitz-Class Carrier

Fiscal year 1997 dollars in millions	
	Total cost
Initial core	
Uranium	\$24
Fuel core procurement	308
Fuel installation	12
Fuel removal at midlife	150
Replacement core	
Uranium	24
Fuel core procurement	308
Fuel installation	64
Fuel removal at inactivation	85
Life-cycle nuclear fuel cost	\$975

Note: Numbers may not add due to rounding.

Source: Navy.

The uranium costs shown were based on what it cost to manufacture during the late 1980s, when it was last manufactured for the Navy. The uranium used to fuel nuclear reactors is supplied by DOE.⁸ DOE ceased production of defense grade uranium in 1991. There is sufficient uranium to operate the Navy's nuclear force for decades. Excess uranium can be reconfigured and sold to private utility companies for use in commercial reactor plants. An alternative cost methodology based on the opportunity cost for the uranium appears in appendix I.

Table 3.9 provides a comparative summary of fuel costs for conventionally and nuclear-powered carriers.

Table 3.9: Comparison of Life-Cycle Fuel Cost for Conventionally and Nuclear-Powered Carriers

Fiscal year 1997 dollars in millions		
Fuel type	Total life cost	Annualized cost
CVN nuclear fuel	\$975	\$19.5
CV fossil fuel	\$738	\$14.8

Source: Our analysis of Navy data.

⁸All domestic enrichment services were handled by DOE until 1993, when these operations were transferred to the United States Enrichment Corporation.

Depot Maintenance Cost

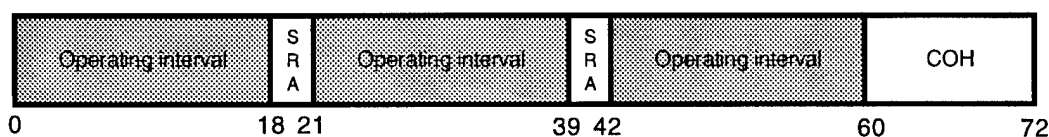
We estimate that the life-cycle cost for depot maintenance for a conventional carrier is about \$4.1 billion compared to about \$5.7 billion for a nuclear carrier. Depot maintenance activities include routine maintenance, repairs, alterations, and fleet modernization expected to be performed over the life of the carrier. Midlife modernization activities, although performed at the depot-level, are not included in our estimated depot maintenance cost. Rather, they are included as part of investment costs.

Our cost estimates were not based on the historical depot maintenance costs captured by the Navy's VAMOSC database for several reasons. First, the cost data collected for the nuclear carriers reflected depot maintenance performed under the Engineered Operating Cycle (EOC) maintenance plan. Since the Navy is changing its depot maintenance strategy for nuclear carriers, we did not believe that historical costs would provide the best estimate for depot maintenance costs. Second, the VAMOSC data, which captured costs for each fiscal year between 1985 and 1994 and the 10-year average cost, could lead to over- or underestimating this cost because of the carriers' age. For instance, the average depot maintenance cost for nuclear carriers reflected maintenance and fleet modernization work performed on nuclear ships that had been in commission, on average, 10 years or less. Conversely, the average depot maintenance cost for conventional carriers reflected maintenance and fleet modernization work performed on carriers that had been in commission for an average 25 years.

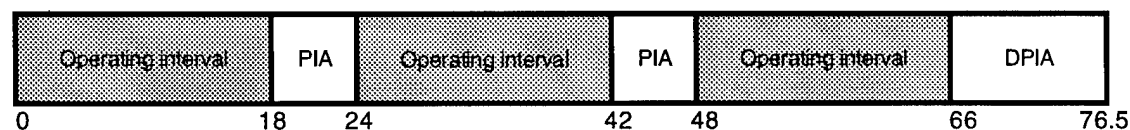
Because of these reasons, we developed depot maintenance cost estimates based on the Navy's notional plans for routine maintenance and fleet modernization for conventionally and nuclear-powered carriers. Estimates of how often depot maintenance will be needed (interval), how many months the ship will be in maintenance (duration), and how much shipyard labor (labor workdays) will be needed for the carrier are guided by the Chief of Naval Operations. Figure 3.5 shows the notional depot maintenance cycle for the two carrier types.

Figure 3.5: Notional Depot Maintenance Cycle for Conventionally and Nuclear-Powered Carriers (in months)

Conventional Carrier



Nuclear Carrier



Notes:

	Duration (in months)		Labor workdays (in thousands)	
	CV	CVN	CV	CVN
COH = Complex Overhaul	12	na	495	na
DPIA = Docking Planned Incremental Availability	na	10.5	na	340 - 437
Operating interval generally includes a deployment	18	18		
PIA = Planned Incremental Availability	na	6	na	194 - 248
SRA = Selected Restricted Availability	3	na	77	na

Source: Navy.

To estimate depot maintenance cost, we determined the number and types of depot maintenance periods that would occur over each of the carrier's 50-year service life. Based on the Navy's notional plans, we determined that the nuclear carrier would need about 38 percent more workdays of labor for anticipated depot-level maintenance and fleet modernization over its 50-year life than the conventional carrier. Next, we developed an estimated cost for each type of depot maintenance by multiplying the number of labor workdays⁹ by the composite labor workday rates¹⁰ for

⁹The Navy provided labor workdays estimated for both maintenance and fleet modernization for each type of depot maintenance.

¹⁰The Navy provided composite public and private shipyard rates that are the average cost for labor and overhead.

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public and private shipyards. We estimated additional depot costs for materials, centrally procured equipment, spare parts, and other miscellaneous items based on our analysis of historical costs for these items. Table 3.10 summarizes the estimated depot maintenance and fleet modernization costs for nuclear and conventional carriers.

Table 3.10: Life-Cycle Cost for Depot Maintenance of a Conventionally and a Nuclear-Powered Carrier

Fiscal year 1997 dollars in millions			
Depot maintenance type	Number in lifetime	Cost per type	Life-cycle cost
CV			
SRA	17	\$51.3	\$872
COH	6	543.0	3,258
Total			\$4,130
CVN			
PIA1	2	\$188.3	\$377
PIA2	4	214.6	858
PIA3	9	240.8	2,167
DPIA1	1	327.7	328
DPIA2	2	376.8	754
DPIA3	3	421.2	1,263
Total			\$5,746

Note: Numbers may not add due to rounding.

Source: Our analysis of Navy data.

The actual depot maintenance cost for the nuclear carrier could be more than our estimate and lower than our estimate for the conventional carrier because we used composite or average shipyard labor rates. However, our earlier work¹¹ showed that the actual labor cost for nuclear work was higher than the labor cost for nonnuclear work. Specifically, we found that the average cost of \$213 per workday for nuclear labor (then-year dollars) was 25 percent more than the average cost for nonnuclear labor, which was about \$170 per workday. We also found that the applied overhead for nuclear work was an average of \$303 per workday, nearly 60 percent more than the average overhead of \$189 per workday for nonnuclear work.

Maintenance of nuclear ships costs more due to the complex nature of nuclear work. Shipyards must provide a greater level of service, pay higher

¹¹Nuclear-powered Ships: Accounting for Shipyard Costs and Nuclear Waste Disposal Plans (GAO/NSIAD-92-256, July 1, 1992).

costs for specially trained and skilled workers, and maintain specialized shipyard departments that support nuclear work, such as radiological controls, nuclear engineering, nuclear planning, and nuclear quality assurance. In addition, shipyards must make provisions to package and dispose of nuclear waste that is generated during maintenance. The cost to process low-level waste generated during maintenance was included in the depot maintenance cost estimate. Parts and other materials used in nuclear systems are often of a unique design and require specialized material.

Indirect Operation and Support Costs

A significant sustaining base is needed to support both the nuclear and the conventional carriers. Some examples include logistics services, training, engineering, and software support. The VAMOSC database captures many of the costs for these activities and reports a portion of the costs as an indirect operating and support cost for each ship. However, we identified several supporting activities and functions that were not captured or were partially captured by that database, such as training, fossil fuel delivery and nuclear support activities.

Indirect support costs for a nuclear carrier are significantly more than those for a conventional carrier. We estimate a nuclear carrier's indirect support cost—\$3.2 billion—is nearly five times more than the estimated \$0.69 billion for a conventional carrier. This difference is primarily due to several expensive activities that support the nuclear carrier but are not needed for the conventional carrier.

Training Cost

We estimate that the Navy spends nearly \$1 billion more to provide a steady flow of trained personnel to operate and maintain a nuclear carrier's propulsion plant than it does to train personnel to operate and maintain a conventional carrier's propulsion plant. The primary reason is the nuclear carrier has a greater requirement for personnel with specialized skills than a conventional carrier does.

Our estimate was not based on the historical VAMOSC database because it does not capture certain training costs that are central to the differences in the propulsion system, nor does its allocation method provide visibility to reasons for the cost difference. Therefore, we developed estimates for initial and specialized training pipeline costs for both carrier types.

To estimate indirect training cost, we used a methodology similar to one developed by the Navy's Center for Cost Analysis. The methodology is

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based on determining the annual training requirement needed to provide a steady flow of skilled personnel that are required in the propulsion plant departments for each carrier type. The annual training requirement is determined by the number of billets, crew turnover, and attrition.¹² For our analysis, we determined the annual training requirement initial skills training for four enlisted ratings (machinist's mates, electrician's mates, electronics technicians and boiler technicians)¹³ and the annual training requirement for additional specialized¹⁴ training beyond the initial level. We selected these skill types because they accounted for most of the difference between the required skills for propulsion plant departments of the two types of carriers. We also determined the annual training requirement for specialized officers skills.¹⁵ Using information provided by the Navy, we identified the training courses required for these skills, and the Chief of Naval Education and Training provided the cost per graduate for each course. The Chief of Naval Education and Training did not have cost information for the required 26 weeks for practical training required for specialized officer and enlisted nuclear skills. Therefore, we estimated the cost per officer and enlisted student based on Navy budget data. Table 3.11 compares the indirect training costs.

¹²Annual training requirement = ((billet /turnover) *attrition).

¹³As of October 1, 1996, the boiler technicians rating was merged with the machinist's mates rating.

¹⁴We focused on Navy Enlisted Classifications (NECs) that are earned after required training has been satisfied.

¹⁵We focused on additional qualification designation (AQD) for officer billets, which indicated a requirement for skills and knowledge beyond those implicit by the officer's billet classification or submarine specialty.

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Table 3.11: Propulsion Plant Pipeline Training Costs for a Conventionally and Nuclear-Powered Carrier

Fiscal year 1997 dollars in millions				
	Initial training	Special training	Annual cost	Life-cycle cost
Conventional carrier				
Enlisted	\$2.50	\$0.71	\$3.21	\$160.62
Officers	^a			
Total	\$2.50	\$0.71	\$3.21	\$160.62
Nuclear carrier				
Enlisted	\$4.28	\$16.47	\$20.75	\$1,037.57
Officers	^a	1.38	1.38	69.10
Total	\$4.28	\$17.85	\$22.13	\$1,106.67

Note: Numbers may not add due to rounding.

^aOur model assumed the training cost for officer's initial training would be the same for both carriers.

Source: Our analysis of Navy data.

Fossil Fuel Delivery

We estimate that it costs about \$469 million to deliver fossil fuel to a conventional carrier over its lifetime. Our estimate is based on a Navy methodology¹⁶ that allocates a portion of the annual operating and support cost for these facilities and ships to each barrel of fossil fuel issued. For example, since Navy depots store fuels other than fossil fuel, the total cost to operate and maintain these facilities is allocated based on the proportion of fossil fuel to total fuel issued from each depot. This cost is then divided by the number of barrels of fossil fuel delivered to produce the delivery cost per barrel. The same method was used to determine the cost per barrel for the Navy ships and oilers operated by the Military Sealift Command (MSC) that deliver fossil fuel. Table 3.12 shows how the fossil fuel delivery cost of \$18.77 per barrel cost was computed. Assuming a conventional carrier uses about 500,000 barrels of fossil fuel per year, or 25 million barrels over its lifetime, we estimate that it will cost about \$469 million to deliver fuel to the conventionally powered carrier.

¹⁶The Navy's cost methodology, which has been used for many years, includes an annualized acquisition cost as well as the annual operating and support cost. However, our analysis does not include an allocation of acquisition cost because we did not have comparable acquisition cost data for facilities (i.e., DOE laboratories) that support the delivery of nuclear power to the Navy's fleet.

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Table 3.12: Cost to Deliver Fossil Fuel to a Conventionally Powered Carrier

Fiscal year 1997 dollars

Activity/ship type	Annual operating and support	Portion allocated to fuel delivery	Cost allocated for fuel delivery	Barrels of fuel issued	Cost per barrel
Fleet supply centers ^a	\$54,295,049	41.77%	\$22,679,042	10,526,000	\$2.19
Ships					
Navy ships ^b	\$294,480,540	45-65%	\$144,815,575		
MSC oilers	\$273,057,960	100%	\$273,057,960		
Total	\$567,538,500		\$417,873,535	25,198,595	\$16.58
Total per barrel delivery cost					\$18.77
Number of barrels delivered over a conventional carrier's lifetime				25,000,000	
Total cost to deliver					\$469,250,000

Note: Numbers may not add due to rounding.

^aThe cost per barrel for the fleet supply centers also includes an allocation of \$0.04 for the annual operation of service craft.

^bNavy ships included are the AO, AOE, and AOR class ships. The percentage of the ship cost allocated to the delivery of fossil fuel varied from 45 to 65 percent.

Source: Our analysis of Navy data.

Nuclear Support Activities

We estimate that it will cost about \$2.04 billion to provide supporting services to the nuclear carriers. Most of this cost is due to the work performed by the activities of the Bettis and Knolls Atomic Power Laboratories, large research and engineering facilities that are solely dedicated to support the Navy's nuclear propulsion program.

More than half of the laboratories' activities are funded through the DOE appropriation for the Naval Nuclear Propulsion Program. DOE's budget for the Program averaged \$731 million annually during the 1990s. Program activities are primarily focused on operational research, development, and testing¹⁷ for the purpose of gaining a better understanding of reactor behavior fundamentals, evaluating reactor performance, and verifying and improving the accuracy of models. The laboratories evaluate cladding, structural, and component materials suitable for use in the operating nuclear plant and develop and test nuclear fuel. The laboratories also evaluate equipment and systems that transfer, convert, store, control, and

¹⁷The Navy's research development test and evaluation budget is the source for obtaining funds needed for specific development, test, and evaluation of new reactors. For example, about \$413 million (then-year dollars) of the budget for fiscal years 1994 to 1998 will fund the laboratories' development of the reactor for the New Attack Submarine. These funds are not included in this discussion.

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measure power that the naval reactor has created. The DOE-funded activities are an integral and necessary component to providing effective military nuclear propulsion plants to the Navy and to ensure their safe and reliable operation.

In addition to the support provided by DOE, the Navy also budgets about \$200 million in operation and maintenance funds to provide essential technical and logistical support for its operational reactors. The types of activities include routine maintenance and engineering support, inspection and refurbishment of reactor plant components, safety surveillance at shipyards, and power plant safety assessments.

Our cost estimate was based on allocating a portion of the annual cost for these activities to a nuclear carrier. For the DOE-funded activities, we allocated 5 percent of DOE's average funding between fiscal year 1991 and 1997 and 2.08 percent of the Navy's average funding between fiscal year 1994 and 1996 for Navy support activities (see table 3.13).

Table 3.13: Cost to Provide Nuclear Support Activities to a Nuclear Carrier

Fiscal year 1997 dollars in millions

	Annual cost	Percent allocated	Allocated annual cost	Life-cycle cost
Energy-funded	\$731.0	5.0 ^a	\$36.6	\$1,828
Navy-funded	208.4	2.08 ^b	4.3	217
Total				\$2,045

Note: Numbers may not add due to rounding.

^aDOE activities were allocated on the basis of a nuclear carrier's demand for power in relationship to other nuclear ships in the Navy's fleet. (See app. I for additional information regarding the relative demand for power nuclear ships.)

^bThe Navy-funded activities were allocated based on our analysis of the number of reactor plants supported by these funds.

Source: Our analysis of DOE and Navy data.

Nuclear Carriers Are More Costly to Inactivate and Dispose of Than Conventional Carriers

Nuclear carriers are significantly more expensive to inactivate and dispose of than conventional carriers. The cost to inactivate and dispose of a nuclear carrier is estimated at \$887 million. In addition, it will cost the Navy an estimated additional \$13 million to provide long-term storage¹⁸ of the spent nuclear fuel (SNF) after it is removed from the carrier's reactor plant. On the basis of Navy data, we estimate that the cost to inactivate and dispose of a conventional carrier is \$52.6 million.

Carrier Disposal Cost

A conventional carrier can be placed in the reserve fleet or retained as a mobilization¹⁹ asset at the end of its service life. When the Navy no longer needs a conventional carrier, it can transfer the carrier to the Maritime Administration, sell the carrier to a private firm or foreign government, or sell the carrier for its scrap value. Our estimate of \$52.6 million to inactivate and dispose of a conventional carrier is based on Navy data and includes the cost to place the carrier in reduced mobilization status, 3 years maintenance in a reduced mobilization status, and final disposal cost less scrap value.

These are not realistic options for a nuclear aircraft carrier because of its nuclear propulsion systems. A nuclear ship is constructed with a nuclear power plant inside a section of the ship called the reactor compartment. The components of the nuclear power plant include a high-strength reactor vessel, heat exchangers (steam generator), and associated piping, pumps, and valves. Each reactor plant contains over 100 tons of lead shielding, part of which is made radioactive by contact with the radioactive material. At the end of its useful service life, the nuclear carrier and its radioactive materials must be disposed of.

Although a nuclear carrier has never been disposed of, the basic steps necessary to dispose of a carrier would be similar to those performed on nuclear submarines and surface ships. The first step is defueling the reactor plant. The highly radioactive SNF is removed from the reactor and sent to the Naval Reactor Facility, located at DOE's Idaho National Engineering and Environmental Laboratory for examination and temporary storage. (Disposition of spent nuclear fuel is discussed later in this chapter.) Next, piping systems, tanks, and vessels are drained; the radioactive systems are sealed; and the reactor compartment is sealed and enclosed in a high integrity steel package. Reactor compartments removed

¹⁸Radioactive materials will need safe storage for thousands of years. Our estimate is based on the radioactive materials storage requirement during the first 100 years after a carrier is commissioned.

¹⁹The Navy keeps three carriers in Mobilization B status. When a carrier is taken out of active service, it is placed in a Mobilization B status; the oldest carrier in Mobilization B status is then disposed of.

from submarines have been transported by barge from Puget Sound Naval Shipyard to DOE's Hanford, Washington, site for final burial.

The Navy provided us with a cost range of between \$818.6 million and \$955.5 million to dispose of the first Nimitz-class nuclear-powered carrier. We used the mid-point cost in our analysis—\$887 million. Most of the cost can be attributed to defueling and removing contaminated nuclear equipment and material. This estimate did not include the cost associated with storing the SNF or any cost associated with maintaining oversight of the reactor plant's burial site in Hanford.

Spent Nuclear Fuel Storage

Spent nuclear fuel (SNF) will be removed from the carrier's reactor plant twice during the Nimitz-class carrier's service life—at its midlife and at inactivation. Because it is highly radioactive, SNF will need to be safely stored for thousands of years. Based on estimates recently provided in DOD's official comments on our draft report, the Naval Nuclear Propulsion Program now estimates it will cost about \$13 million to safely store the SNF during the first 100 years after a nuclear-powered carrier is decommissioned using a new dry storage method (see table 3.14). We were unable to verify the accuracy and completeness of this estimate but we do know that the new method promises to be significantly less expensive than the method formerly used, called the wet storage method.

Table 3.14: Navy Cost Estimate for the Dry Storage of a Nuclear-Powered Carrier's Spent Nuclear Fuel

Fiscal year 1997 dollars in millions	
	Cost
Initial cores	
Hardware per ship set of cores	\$ 4.8
Operational costs for 75 years of dry storage	1.8
Replacement cores	
Hardware per ship set of cores	4.8
Operational costs for 50 years of dry storage	1.7
Total cost	\$13.0

Note: Numbers may not add due to rounding.

Source: Naval Nuclear Propulsion Program.

The Navy has been temporarily storing its SNF using a wet storage method. Under this method the nuclear propulsion program stores the fuel in special pools located at DOE's Idaho National Engineering and

Environmental Laboratory. The water in the pools serves the dual purpose of acting as the barrier for the radiation and dispersing the heat in the SNF. Using this method, DOE estimated that it would cost about \$306 thousand to receive and place the Nimitz-class cores into the storage pools and an additional \$1.144 million for each year the cores are stored. The storage cost begins to accumulate after the first cores are removed during the carrier's refueling complex overhaul near its 25th year of service. The storage cost will double when the replacement cores are removed upon carrier inactivation. Temporary storage costs for naval SNF are likely to change as the Navy transitions²⁰ to the dry storage method. Table 3.14 reflects the anticipated savings from adopting the new method of spent nuclear fuel storage.

Ultimately, SNF will have to be permanently disposed of, which will present an extremely difficult challenge because it will remain dangerous for thousands of years. The national strategy focuses on disposal of SNF generated by civilian nuclear power plants and high-level waste in a geologic repository. DOE is responsible for developing an underground repository. However, DOE does not expect that the repository will be operational until about 2010,²¹ more than 10 years behind that envisioned. Thus, estimating the cost is complicated because the current repository plans were not based on disposing defense-grade SNF, such as that from naval reactor plants, but on the high-level waste that is generated from reprocessing defense-grade SNF. Thus, we did not estimate final disposal costs for the carrier's SNF but instead focused on the current storage practices.

Agency Comments and Our Evaluation

DoD partially agreed with our life-cycle analysis. DoD agreed that a thorough understanding of total life-cycle costs is key to allocating scarce resources. However, DoD disagreed that comparing the life-cycle costs of conventionally powered carriers such as the U.S.S. John F. Kennedy with Nimitz-class nuclear-powered carriers was appropriate because of differences in the age, size, and capabilities of the carriers.

DoD agreed that the life-cycle cost of nuclear-powered carriers is greater than conventionally powered carriers but that the premium is not as large

²⁰In October 1995, the state of Idaho, the Navy, and DOE reached an agreement regarding the shipment and storage of SNF in Idaho. As a result, all SNF located at DOE's Idaho site will be placed in dry storage by 2023 and all SNF will be removed from Idaho by 2035.

²¹Nuclear Waste: Foreign Countries' Approaches to High-Level Waste Storage and Disposal (GAO/RCEID-94-172, Aug. 4, 1994) and Nuclear Waste: Comprehensive Review of the Disposal Program Is Needed (GAO/RCEID-94-239, Sept. 27, 1994).

as estimated by us. DOD did not agree with our approach of making cost-per-ton comparisons between nuclear-powered Nimitz-class carriers and conventionally powered carriers such as the Kennedy. DOD believed that it would be more appropriate to compare conventionally and nuclear-powered carriers with equivalent capabilities.

While the nuclear-powered Nimitz-class carrier and the conventionally powered Kennedy-class carrier are not identical, we chose to compare them because the Kennedy was the last and largest conventionally powered carrier built, it employs an airwing of comparable size to that of the Nimitz-class carriers, and there was adequate historical data available. Further, both classes of carriers have performed the same missions for more than two decades.

Our estimate of the difference in costs between the two types of carriers is greater than DOD's estimate primarily because of differing methodologies. Our acquisition cost estimate was based on a cost-per-ton methodology, which is an accepted method for estimating these costs and has been used by the Navy and others. The actual acquisition cost for the Kennedy, adjusted for inflation, is virtually the same as the acquisition costs used in our estimate. According to the Navy, it estimated the cost for a "new" conventionally powered carrier with the capabilities of the newest Nimitz-class carriers and assumed the conventionally powered carrier would have a larger displacement than a Nimitz-class carrier. It stated that the conventionally powered carrier's cost was based on actual manhours adjusted to reflect manhour and material growth over 30 years. Navy officials told us they assumed the conventionally powered carrier would be constructed at Newport News Shipbuilding and therefore used that company's cost factors (for example, labor rates, overhead rates, and material rates). In addition, because the Navy did not include the cost of the Kennedy's SLEP when it calculated the average cost for a CV SLEP, its estimate was greater than ours.

Our operating and support costs were based on historical data for the conventionally powered Kennedy-class and the nuclear-powered Nimitz-class. The DOD estimate is based on estimates of a much larger conventionally powered carrier as discussed above. We also used different methodologies for estimating indirect costs (see app. VII, comments 33, 34, and 35). The Navy chose to estimate personnel cost using its Manpower Billet Cost Factor Model. This model is intended to estimate the full manpower cost, including indirect cost, such as training. We did not use this model because much of the nuclear training costs are not captured by

that model. Instead, we used validated historical costs to estimate direct personnel costs. We separately estimated training pipeline cost using a methodology developed by the Navy's Center for Cost Analysis.

The Navy also used a different method for allocating the annual cost of DOE's laboratories that support its nuclear fleet. We allocated this cost based on the demand/consumption of nuclear power. Finally, the Navy's new estimate to inactivate and dispose of the CVN is nearly 40 percent less than the estimate used in our analysis. We did not use the Navy's newer estimate because no evidence was provided or found to support the significant reductions in cost to the original estimate provided to us.

DOE concurred with DOD's comments addressing estimates of costs associated with nuclear reactor plant support activities and the storage of SNF. These comments and our evaluation of them are discussed in appendix VII.

Implications of an All Nuclear-Powered Carrier Force on Naval Presence in the Pacific

Homeporting Navy ships overseas enables the United States to maintain a high level of presence with fewer ships because the need for a rotation base to keep forces deployed is smaller. The homeporting of a conventionally powered carrier at Yokosuka, Japan, provides a level of presence that would otherwise require six nuclear-powered carriers homeported in the United States. However, the Navy has been replacing conventionally powered carriers with nuclear-powered carriers. If this trend continues, the Navy will eventually have to either

- establish a nuclear-capable maintenance facility and related infrastructure in Japan to accommodate a nuclear-powered carrier to be homeported there or
- expand the force to include the additional nuclear-powered carriers that would be needed to keep the same level of presence, but with ships deploying from the United States.

Alternatively, the Navy could either construct a new conventionally powered carrier or accept a lower level of presence.

While it would be several years before the carrier force would have undergone a complete transition to nuclear propulsion, it will also take several years to implement any of the strategies that will allow the United States to maintain a long-term continuous naval carrier presence in the Pacific region.

Conventionally Powered Carrier Force Structure Has Been Declining

The conventionally powered carrier force has declined from nine carriers in fiscal year 1991 to the current force of four conventionally powered carriers.¹ By fiscal year 2008, current Navy plans project there will be one conventionally powered carrier in the force. Three of the current carriers are in the active force and one is assigned to the reserve force. One of the active carriers, the U.S.S. *Independence* (CV-62), is homeported at Yokosuka, while two, the U.S.S. *Kitty Hawk* (CV-63) and the U.S.S. *Constellation* (CV-64), are periodically deployed overseas.² The fourth, the U.S.S. *John F. Kennedy* (CV-67), is considered an operational reserve carrier. It provides Navy and Marine Corps aviators carrier landing training and qualification, participates in exercises, and can be deployed to

¹There were nine conventionally powered carriers in the Navy's force structure from fiscal year 1981 through fiscal year 1991.

²The U.S.S. *Kitty Hawk* (CV-63) is scheduled to replace the U.S.S. *Independence* (CV-62) in fiscal year 1998 as the permanently forwardly-deployed carrier in Yokosuka. The U.S.S. *Independence* (CV-62) will be decommissioned.

fill gaps in overseas presence and help meet crisis response needs. Table 4.1 shows the four carriers now in the force, their last full year of active service, and their age at the end of their estimated service life.

Table 4.1: Conventionally Powered Carrier Force—Last Full Year in Active Service

Carrier	Year	Ship age (in years)
U.S.S. <u>Independence</u> (CV-62)	1997	39
U.S.S. <u>Kitty Hawk</u> (CV-63)	2007	47
U.S.S. <u>Constellation</u> (CV-64)	2002	41
U.S.S. John F. Kennedy (CV-67)	2017	43-50

Source: Navy.

As recently as 1994, the U.S.S. Kennedy was scheduled for decommissioning in fiscal year 2011. However, current long-range Navy carrier construction plans indicate it will be decommissioned in fiscal year 2018, thus adding 7 years to its service life. The remaining service life of the Kennedy will depend on several factors, including whether it undergoes extensive major maintenance and modernization, whether it deploys regularly in support of the active force, or whether it is primarily used as a training carrier. Unlike many of the other conventionally powered carriers, the Kennedy did not receive an extensive service life extension overhaul that would have added 15 years of service life.

Benefits of Homeporting a Carrier in Japan

A conventionally powered carrier has been permanently forward deployed and homeported in Japan since 1973. This carrier provides full-time presence in the Pacific region without the need for long transit times and can respond to a crisis in the region in a matter of days. Providing continuous forward presence is a clear advantage to having an aircraft carrier and its battle group permanently forward deployed in Japan. Additionally, the government of Japan makes significant contributions for the yen-based costs of maintaining U.S. forces in Japan.

The United States and Japan share the cost of basing U.S. forces in Japan through the Special Measures Agreement. Japan also pays for new facilities and improvements the United States uses through the Japanese Facilities Improvement Program. The Program, begun in 1979, is a cost and burden-sharing program funded and administered by the Japanese government. It is not required or protected by any treaty or agreements between the United States and Japan. According to Pacific Command and

Pacific Fleet officials, the Program could fund construction of the additional maintenance facilities to permanently homeport a nuclear-powered carrier in Japan.

Japan contributes more than 70 percent of the total yen-based cost of stationing U.S. forces there (more than \$5 billion in 1995). These contributions include aircraft carrier maintenance and repairs performed by the Japanese work force at the U.S. Naval Ship Repair Facility, Yokosuka. Currently, these facilities have no nuclear repair capability. If the carrier now homeported in Japan were to return to a U.S. homeport, the United States would incur all maintenance costs. For nuclear-related maintenance to be conducted at the U.S. Naval Ship Repair Facility, Yokosuka, several infrastructure improvements would be required and the maintenance would be performed by U.S. shipyard workers at U.S. expense.

Homeporting a Nuclear-Powered Carrier in Japan Could Be Difficult and Costly

Homeporting a nuclear-powered carrier permanently at Yokosuka would require a major base reorganization, including nuclear-propulsion maintenance and support facilities, upgraded utilities, and dredging of the harbor and approach to accommodate a deeper draft ship. It would also require additional family housing and support facilities. Although funds could be obtained through the Japanese Facilities Improvement Program, the approval process could be lengthy. The Department of State noted that the entry into Japanese ports of nuclear-powered vessels remains sensitive in Japan and that there would have to be careful consultations with the Government of Japan should the U.S. Government wish to homeport a nuclear-powered carrier in Japan.

Facilities and Port Improvements

The Navy's requirements for additional facilities to support a nuclear-powered carrier homeported at a base that supports conventionally powered carriers are described in the Navy's March 1995 report entitled Nimitz-Class Aircraft Carrier Homeporting Cost Comparison Between NAS (Naval Air Station) North Island and NSY (Naval Shipyard) Long Beach. Each facility's requirements will differ based on what exists at the facility. The facilities and port improvements being made to accommodate the homeporting of a nuclear-powered carrier at Naval Air Station, North Island in San Diego, which is already capable of homeporting conventionally powered carriers, illustrates what improvements may be needed to expand the maintenance, harbor, and

infrastructure capabilities of the conventionally powered carrier homeport in Yokosuka, so that it could accommodate a nuclear-powered carrier.

The facilities planned for the nuclear-powered carrier homeport at the North Island Naval Air Station are similar to those at Puget Sound Naval Shipyard. The North Island facilities include an aircraft carrier wharf, a controlled industrial facility, a ship maintenance facility, and a maintenance support facility. Other projects at North Island include the dredging of the harbor channel and a turning basin for the ship. Also, upgraded power would be required at the ship berthing. The controlled industrial facility and ship maintenance facility provide depot-level repair and maintenance of nuclear propulsion plant systems and components. The total area required for these facilities is the equivalent to 4-1/2 football fields. The projects at North Island are estimated by the Navy to cost about \$260 million.

According to facilities and logistics officials from the Pacific Command, Pacific Fleet, and Navy headquarters, in addition to the nuclear maintenance facilities, other improvements would be needed at Yokosuka to support a homeported nuclear-powered carrier. For example, a larger, stronger pier would be needed to accommodate the larger, heavier nuclear-powered carrier and cranes for pier-side maintenance. Also, upgraded and expanded electrical power supplies would be needed to run the reactor coolant pumps while the ship is berthed. Additional substations would be required for redundancy, and commercial power would also have to be upgraded. Access to controlled pure water would also be required.

According to these officials, Nimitz-class aircraft carriers need harbors and pierside-areas dredged to 50 feet or more, compared to a 45-foot depth for conventionally powered carriers. The harbor and pier side at Yokosuka would need to be blasted and dredged, because of the rock bottom, to accommodate a nuclear-powered carrier. Other improvements could include modifications to the drydock and associated equipment. However, the Navy has not conducted a survey to identify specific drydock improvements needed to support a nuclear-powered carrier at Yokosuka.

Limited Space for Additional Facilities

The Navy restricts access to nuclear propulsion system components to U.S. citizens, even though some of the components are the same used in conventionally powered ships. Restrictions on access to nuclear propulsion components require separate facilities for nuclear maintenance

and general ship repair. However, according to Pacific Command officials, there is little room at Yokosuka for additional maintenance facilities. Thus, providing additional maintenance facilities would require replacing existing structures; however, Yokosuka's existing conventional carrier maintenance facilities are spread over several buildings throughout the facility.

According to Department of State officials, there may be space constraints at Yokosuka that could make the homeporting of nuclear-powered aircraft carriers difficult. The port of Yokosuka is congested. The city of Yokosuka is adjacent to the base, which also limits expansion.

**Family Housing and Other
Personnel Support
Facilities Already Stressed**

Family and bachelor housing shortages are severe at Yokosuka. According to the Deputy Chief of Staff, Shore Installation Management, U.S. Pacific Fleet, the base needs over 1,200 additional units. The planned homeporting of additional and larger surface combatants at Yokosuka will increase the need for additional housing. For example, homeporting a nuclear-powered carrier could add about 200 families. The housing situation could be further exacerbated with the addition of hundreds of U.S. workers to work on nuclear-related equipment during maintenance periods. The additional personnel would add to the requirement for commissaries and recreation and other support facilities.

Lengthy Approval Process

According to Pacific Command officials, facility improvements at Yokosuka could be funded through the Japanese Facilities Improvement Program. However, obtaining approval is a lengthy process. For example, a family housing project took 10 years to obtain approval and funding. Pacific Command officials estimated it could take between 7 to 15 years to obtain approval for nuclear-powered carrier homeporting facilities improvements.

Other Overseas Homeports

The Navy's 1994 Naval Forward Presence Report stated that forward homeporting a nuclear carrier overseas is problematic because of potential host nation opposition as well as the complexity of nuclear-related maintenance that might require the ship to return to the United States for repairs. The report estimated that the establishment of a nuclear-capable maintenance facility at an overseas location would be expensive and politically unacceptable.

Providing Regional Presence With Carriers Homeported on the West Coast

The Pacific Command's policy requires continuous presence of an aircraft carrier in the Pacific region. The carrier now permanently forward deployed in Japan provides this level of presence. Based on our analysis using the Navy's Force Presence Model and data, we found the single, conventionally powered carrier permanently forward deployed in Japan provides forward presence coverage in the Pacific region that would require six nuclear-powered carriers homeported at West Coast ports of the United States. Reducing regional presence requirements to 75 percent still would require four nuclear-powered carriers in an all nuclear-powered force.

The requirement for an increased number of nuclear-powered carriers when based out of the United States is a function of deployment cycle policies and requirements, including a maximum 6-month deployment, the need for post deployment shipyard maintenance, predeployment training and exercises, and the deployment transit distance and speed. (See chs. 1 and 2 for a more complete discussion.) However, the Navy currently does not have the infrastructure to support additional nuclear-powered carriers at West Coast homeports.

Agency Comments and Our Evaluation

DOD partially concurred with the discussion of the difficulties associated with homeporting and maintaining a nuclear-powered carrier in Japan. According to DOD, infrastructure changes would not be as significant as we portray because the non-propulsion plant maintenance would continue to be supported by Ship Repair Facility, Yokosuka. DOD said that if a nuclear-powered carrier was homeported in Japan, maintenance plans could be modified to improve the ability of the ship's force to maintain the propulsion plant, augment the ship's force with "fly-away" teams, and periodically return the ship to the United States for depot-level maintenance and replace it with another carrier. DOD agreed that some changes in base support infrastructure would be required if a nuclear-powered carrier was homeported in Japan.

Our discussion of the implications of homeporting a nuclear-powered carrier in Japan was based, in part, on the Navy's current maintenance strategy. We note the Navy has not modified that strategy. Further, we note that significant changes in base support infrastructure would be required to accommodate a nuclear-powered carrier homeported in Japan. We note that the Navy made significant and costly infrastructure changes at North Island Naval Air Station when it decided to homeport a nuclear-powered carrier there.

Chapter 4
Implications of an All Nuclear-Powered
Carrier Force on Naval Presence in the
Pacific

The Department of State noted in its only comment on the draft report that the entry of nuclear-powered vessels into Japanese ports remains sensitive in Japan and there would have to be careful consultations with the government of Japan should the U.S. government wish to homeport a nuclear-powered carrier in Japan.

Objectives, Scope, and Methodology

The Defense Appropriations Act of 1994 Conference Report directed us to study the cost-effectiveness of nuclear-powered aircraft carriers. Our objectives were to (1) evaluate the adequacy of conventionally and nuclear-powered aircraft carriers in meeting the Nation's forward presence, crisis response, and war-fighting requirements and (2) estimate the total life-cycle costs of conventionally and nuclear-powered aircraft carriers. The conferees noted the study should include (1) a life-cycle cost analysis that includes the cost of processing and disposing of nuclear waste and spent fuel, (2) an estimate of the costs associated with processing and disposing of nuclear fuel and other nuclear material for the existing nuclear-powered fleet, and (3) the implications of an all nuclear carrier force on overseas homeporting. An evaluation of aircraft carrier and/or industrial base issues was not included in our scope of work.

In performing our analysis, we reviewed policy directives, planning guidance, strategies, threat assessments, operational histories, statistics, schedules, studies, and assessments on conventionally and nuclear-powered carriers. We reviewed and conducted analyses using the Navy's Force Presence Model to gain an understanding of the various factors that affect the required numbers of carriers to achieve various overseas presence levels, and examined the Navy's assessments of aircraft carrier requirements for presence. We also reviewed several Department of Defense (DOD) and Navy studies, for example, the Naval Forward Presence Report; several historical cost-effectiveness studies, including Nuclear Power for Surface Warships, the Sea-Based Air Platform Cost/Benefit Study, and the Carrier 21 Study; the Report on the Bottom-Up Review; defense guidance; and other documents relevant to understanding how assumptions on key operational and cost factors affect plans, programs, and operations. We consulted with officials of the Joint Staff, the Office of the Secretary of Defense, the Navy, and the Center for Naval Analyses to develop and concur with our proposed measures of effectiveness—peacetime presence, crisis response, and war-fighting. In addition, we met with agency officials to obtain information on new technologies and system improvements and future aircraft carrier requirements, capabilities, and operations.

To understand how the Navy has and is using its carrier force during peacetime, crises, and war, we discussed past and current naval operations with U.S. Atlantic Fleet and U.S. Pacific Fleet officials. We also talked with officials of the Joint Staff and the Atlantic, Pacific, and Central Commands to obtain their perspectives on how the conventionally and nuclear-powered carriers support their strategies, plans, and operations.

We met with battle group commanders and carrier commanders and their staffs from both conventionally and nuclear-powered carriers and examined briefings on recent deployments to understand the role, use, and missions of the conventionally and nuclear-powered carriers. In addition, we toured both conventionally and nuclear-powered carriers to discuss ship and air wing operations and capabilities with the ships' and air wings' commanders and staff. We also met with the Combat Logistics Fleet Commander for the Atlantic Fleet, the Combat Logistics Fleet Chief of Staff for the Pacific Fleet, and the commanding officer of the U.S.S. Sacramento, a fast combat support ship that directly supports the battle group.

To gain an understanding of nuclear propulsion cost, technology, and the nuclear fuel cycle, we talked with officials of the Naval Nuclear Propulsion Program and visited facilities and laboratories dealing with naval nuclear propulsion research and development, test, and evaluation; training; fuel processing; and radioactive waste management.

We talked with experts and academicians from both public and private organizations to obtain additional perspectives covered in our visits with U.S. military and defense officials. We performed our fieldwork from February 1995 to February 1997 at the following locations :

Washington, D.C., area

- Office of the Secretary of Defense
- The Joint Staff
- Office of the Chief of Naval Operations
 - Naval Nuclear Propulsion Program
 - Bureau of Naval Personnel
 - Deputy Chief of Naval Operations (Plans, Policy, and Operations)
 - Deputy Chief of Naval Operations (Logistics)
 - Air Warfare Division, Deputy Chief of Naval Operations (Resources, Warfare Requirements, and Assessments)
 - Assessment Division, Deputy Chief of Naval Operations (Resources, Warfare Requirements, and Assessments)
- Naval Sea Systems Command
 - Aircraft Carrier Program Management Office
 - Cost Estimating and Analysis Division
 - Engineering Directorate
- Naval Center for Cost Analysis
- Ships History Branch, Naval Historical Center

- Defense Intelligence Agency
- Commission on Roles and Missions of the Armed Forces
- Headquarters, Department of Energy
- Headquarters, Department of State
- Institute for Defense Analyses
- Center for Naval Analyses

Norfolk, Virginia, area

- Headquarters, U.S. Atlantic Command
- Headquarters, U.S. Atlantic Fleet
- Naval Air Force, U.S. Atlantic Fleet
- Naval Surface Force, U.S. Atlantic Fleet
- Carrier Group Eight (Theodore Roosevelt Battle Group) (commanding officer/battle group staff)
- Carrier Group Six (America Battle Group) (commanding officer)
- U.S.S. America (CV-66)
- U.S.S. Theodore Roosevelt (CVN-71)
- Commanding Officer, U.S.S. George Washington (CVN-73)
- Commanding Officer, Logistics Group Two
- Naval Doctrine Command
- Naval Safety Center
- Supervisor of Shipbuilding, Conversion, and Repair (Newport News)
- Newport News Shipbuilding and Dry Dock Company

Tampa Bay, Florida, area

- Headquarters, U.S. Central Command
- Headquarters, Navy Central Command

Seattle, Washington, area

- Commander, Naval Surface Group Pacific Northwest
 - Commander, Task Force 33
 - Commander, Logistics Group One
- Planning, Engineering, Repairs, and Alterations, Carriers (PERA/CV), Naval Sea Systems Detachment
- Puget Sound Naval Shipyard
- U.S.S. Abraham Lincoln (CVN-72) (commanding officer and staff)
- U.S.S. Sacramento (AOE-1) (commanding officer and staff)

Alameda, California, area

- Carrier Group Three (Lincoln Battle Group) (commanding officer/battle group staff)

San Diego, California, area

- Naval Air Force, U.S. Pacific Fleet
- Naval Air Station North Island
- U.S.S. Kitty Hawk (CV-63) (commanding officer, air wing, and department heads)
- U.S.S. Constellation (CV-64) (executive officer, air wing, and department heads and chief of staff, Cruiser-Destroyer Group One)

Honolulu, Hawaii, area

- Headquarters, U.S. Pacific Command
- Headquarters, U.S. Pacific Fleet
- Pearl Harbor Naval Shipyard
- Former Commanding Officer, U.S.S. John F. Kennedy (CV-67) (Deputy Commander, U.S. Pacific Fleet)

Other Locations

- Department of Energy
 - Pittsburgh Naval Reactors Office, West Mifflin, Pennsylvania
 - Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania
 - Schenectady Naval Reactors Office, Schenectady, New York
 - Knolls Atomic Power Laboratory, Niskayuna, New York
 - Kesselring Prototype Reactors Site, West Milton, New York
 - Department of Energy-Idaho Operations Office, Idaho Falls, Idaho
 - Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho
- Chief of Naval Education and Training, Pensacola, Florida
- TradeTech, Denver, Colorado
- The Uranium Exchange Company, New Fairfield, Connecticut

Aircraft Carrier Maintenance Analysis

Our comparison of operating and maintenance time encompassed the aircraft carriers of the Forrestal- (except for U.S.S. Independence), Kitty Hawk-, Kennedy-, and Nimitz-classes. We excluded the U.S.S. Midway and the U.S.S. Coral Sea because they were designed and built during World War II and we believed their age made them unrepresentative. Additionally, the U.S.S. Midway was homeported in Japan during part of the period and, thus, was not subject to the normal maintenance cycle—the same reason we excluded the U.S.S. Independence. We also excluded the U.S.S. Enterprise because, as the first nuclear-powered carrier, it was a unique design and, thus, we believed its data would not be comparable to the ships of the Nimitz-class.

Our comparisons also only include that time the carriers spent undergoing regular depot-level maintenance in a shipyard. Our data also represents the collective experience of the two ship types, not per ship-type averages. That is, we determined the total number of days all conventionally and nuclear-powered carriers were (1) in service during the time period, (2) in a shipyard undergoing depot-level maintenance, and (3) available for operating with the fleet. Our results are based on those totals by propulsion type, not on individual ship, ship class, or ship type averages.

We revised our methodology for adjusting service life extension program (SLEP) time as follows. Three conventionally powered carriers, CV-60, CV-66, and CV-67, underwent complete comprehensive overhauls during the period. The mean length of those overhauls was 436 days. Four ships—CV-59, CV-63, CV-64, and CV-67—underwent SLEP during the time period. Using the original start date of each ship's SLEP, we substituted a 436-day overhaul for each SLEP. We further modified each ship's remaining schedule by eliminating the Post Shakedown Availability/Selected Restricted Availability scheduled after the SLEP and scheduled the next SRA 18 months after the SLEP's completion. We then moved each ship's remaining schedule forward to compensate for the reduced length of the availability. We also added an additional SRA and sufficient operating time to CV-59's schedule to allow it to reach its actual deactivation date of September 15, 1992.

As in our earlier calculations, when calculating depot-level maintenance time for the period October 1, 1997, through December 31, 2007, we excluded the Enterprise and the conventionally powered carriers homeported in Japan. We also excluded the Ronald Reagan since it will be under construction for about half the period.

Conventionally and Nuclear-Powered Aircraft Carrier Cost Model

We developed a life-cycle cost model to estimate the life-cycle costs for both a nuclear and a conventionally powered aircraft carrier. For the nuclear ship, we used data available for the Nimitz-class carrier (CVN-68 class). We selected the Kennedy-class¹ as the comparable conventional carrier for several reasons. The U.S.S. John F. Kennedy (CV-67) was the last and largest conventional carrier built, it employs an airwing of comparable size to that of the Nimitz-class, and there were adequate historical data available.

Our life-cycle cost model includes the cost of nuclear fuel as part of the investment activity: acquisition, refueling complex overhaul (RCOH), and inactivation. Operating and support costs were generally based on historical data for the two ship classes. Our model also included an assignment of indirect cost when the cost was determined to be significant. In each case, we did not determine the incremental or marginal cost of a support activity, but we did allocate a portion of the total annual cost as an indirect cost for the carrier. All costs are expressed in constant fiscal year 1997 dollars, except as noted. As discussed later in this appendix, we also performed a present value analysis to identify any potential differences when the time value of money was considered.

Ship Acquisition Costs

We developed our own estimate for the cost to acquire a conventional carrier based on the historical acquisition cost per ton to build aircraft carriers. Our methodology was similar to one used in our earlier study² and by the Center for Naval Analyses in some preliminary work it did for the Navy as it began to assess its future carrier needs. We determined a ratio between the acquisition cost per ton of the U.S.S. John F. Kennedy (CV-67) and the U.S.S. Nimitz (CVN-68). This ratio was then applied to the Navy's projected acquisition cost per ton of the CVN-76 to provide an estimated acquisition cost per ton for a new conventionally powered carrier. The resulting cost per ton was then multiplied by the Kennedy's displacement to provide a rough order of magnitude acquisition cost. While there are many unknowns involved in estimating the current cost to acquire a ship (conventionally powered carrier) that has not been built for over 25 years, our estimate was based on the best available information we could obtain. For the nuclear carrier, we multiplied the displacement weight for the CVN-76, the most recently authorized Nimitz-class carrier, by the average acquisition cost per ton for the Nimitz-class carriers built.

¹For our analysis, the Kennedy-class includes the CV-63, CV-64, CV-66 carriers that are similar in size, displacement, and crew size and other ship characteristics.

²Navy's Aircraft Carrier Program: Investment Strategy Options (GAO/NSIAD-95-17, Jan. 1995).

Although research, development, test, and evaluation and military construction costs are normally included in developing an acquisition cost estimate, in contrast to the more limited procurement estimate, our estimate did not include several nuclear-related military construction costs because they were not included in the Selected Acquisition Reports for the Nimitz-class. For example, the costs of nuclear maintenance facilities for the nuclear-powered carriers to be homeported in San Diego, California, have not been captured.

Operating and Support Costs

Ship operating and support costs were generally based on the 10-year average cost for the CV-67 and CVN-68 class carriers during fiscal years 1985 through 1994, which were obtained from the Navy's Visibility and Management of Operating and Support Cost (VAMOSC) Management Information System database. Several operating and support cost categories were modified or added because data were not fully captured by the system. The categories we adjusted included personnel, depot maintenance, fossil fuel, indirect training, fossil fuel delivery, and nuclear support structure.

We adjusted the VAMOSC baseline data for direct personnel, depot maintenance, and fuel costs. We modified the personnel cost to capture the cost of accrued retirement by adding an additional 30.6 percent, the percentage for DoD's contribution to its retirement fund for fiscal year 1997. We estimated depot maintenance costs using the Navy's notional maintenance plans for each carrier over its lifetime. We did not use the historical depot maintenance costs captured by the Navy's VAMOSC database for several reasons. First, the cost data collected for the nuclear carriers reflected maintenance performed under the Engineered Operating Cycle (EOC) strategy. Since the Navy is changing its maintenance strategy for nuclear carriers and does not intend to use the EOC strategy in the future, we were not confident that the historical costs would provide the best basis for estimating life-cycle depot maintenance costs. We were also concerned that the VAMOSC data, which captured costs for fiscal years 1985-94, would lead to over- or underestimating costs because of the carrier types' average age. Thus, our estimated maintenance cost was determined by the number, type, and cost for the notional maintenance expected over each of the carrier's life time. Using the Navy's notional plans, we determined the number and type of depot maintenance periods that would occur over each of the carrier type's 50-year service life. To estimate the cost for each type of depot maintenance period, we multiplied

the number of labor workdays³ expected for each type of maintenance times the Navy's composite labor workday rates⁴ for public and private shipyards. We estimated additional maintenance costs for materials, centrally procured equipment, spare parts, and other miscellaneous items based on our analysis of historical costs for these items.

Nuclear fuel cost was provided by the Naval Sea Systems Command's Nuclear Propulsion Directorate. For this analysis, the direct nuclear fuel cost included the procurement of the initial and replacement fuel cores, the uranium used in the cores, and the cost to install and remove the initial and replacement cores. Our estimated cost for fossil fuel was based on the historical average number of barrels a conventionally powered carrier used and the average price per barrel between fiscal year 1991 and 1995 paid by the Navy.

We also modified the VAMOSC baseline data to account for several indirect operating and support cost categories that are affected because of the difference in propulsion systems. These categories include indirect cost for training, fossil fuel delivery system, and nuclear power supporting activities. Indirect cost estimates are generally based on an allocation of the annual cost.

The indirect training cost was based on the personnel training requirement needed to support the specific enlisted ratings in the engineering department of the U.S.S. John F. Kennedy (CV-67) and the engineering and reactor departments of the U.S.S. Nimitz (CVN-68). We selected four ratings (machinist's mates, electrician's mates, electronics technicians and boiler technicians) because the requirements for rating skills were most affected by the type of propulsion plant. The training requirement for these skills was determined by the number of required billets, annual crew turnover, and attrition rates. Using Navy provided crew turnover and attrition rates and the cost per student for initial and specialized skills training, we developed the cost per student for specialized training received at the moored ships and prototypes. Our estimated cost per student was based on 26 weeks of pay and allowance per student plus an allocated portion of the total cost for instructors and base support personnel and operation and maintenance funding for these facilities. Training cost was estimated by multiplying the annual training

³The Navy provided labor workdays estimated for both depot maintenance and fleet modernization for each type of depot maintenance period.

⁴The Navy provided composite public and private shipyard rates that reflected the average labor and overhead cost of work performed.

requirement by the applicable initial and specialized training cost per student.

Indirect fossil fuel delivery cost was based on the Navy's method of determining the fully burdened cost for each barrel of fuel delivered to its fleet of ships. Our methodology allocated a portion of the Navy's total annual cost to operate and maintain its fleet supply activities, service craft, and oilers⁵ to each barrel of fuel delivered. For example, the Navy spends about \$54 million to operate and support its fleet industrial centers. Since these centers store other fuels, we allocated about 42 percent, or \$22.7 million, based on the proportion of fossil fuel to total fuel issued at each center. The \$22.7 million was then divided by 10.5 million, the total number of barrels of fossil fuel issued by the Fleet Industrial Supply Centers, to produce an estimated delivery cost per barrel. A similar method was used to allocate the annual cost to operate and support Navy and Military Sealift Command oilers to each barrel of fuel delivered.

The estimated indirect nuclear support activities cost was based on an allocation of the total costs for these activities. The Navy-funded activities support operational reactor plants and the funding level are directly influenced by the number of plants being supported. There are eight operating reactor plants types, one of which is for the Nimitz-class. Therefore, we allocated 12.5 percent of the Navy's average funding for the Nimitz-class carriers. Since there are six Nimitz-class carriers in the force, one-sixth (or 2.08 percent) of the funding was used to estimate the cost of this support activity for one nuclear-powered carrier. The estimated indirect cost for DOE-funded nuclear supporting activities was allocated based on the nuclear carriers' demand for power (or energy needs). Based on our analysis of uranium consumed and shaft horsepower needs of the nuclear fleet, we determined that the nuclear carrier accounted for about five percent of the total uranium consumed and shaft horsepower required by naval nuclear ships. We allocated 5 percent of the average funding between fiscal year 1991 and 1997 for Energy's Naval Nuclear Propulsion Program as our estimated annual cost of these support activities.

Inactivation and Disposal Costs

Our estimate to inactivate and dispose of a conventional carrier was based on the Navy's estimated cost to place the carrier in reduced mobilization status, 3 years maintenance in mobilization status, and final disposal cost

⁵This includes the AO, AOE, and AOR class ships as well as oilers operated by the Military Sealift Command.

less scrap value. We estimated scrap value based on scrap sales of naval ships during fiscal years 1993 and 1995.

Our estimate to inactivate and dispose of a nuclear carrier was based on data provided by the Navy and the DOE. The Navy provided a cost range to inactivate and dispose of a carrier. We used the mid-point estimate. In its official comments on our draft report, DOD provided a new estimate for the receipt and annual storage of the spent nuclear fuel (SNF) from a Nimitz-class carrier. This estimate, which is based on the dry storage method, is much less expensive than the estimate for the wet storage method. We were unable to verify the accuracy or the completeness of the new estimate but have included it since the dry storage method is generally much less expensive than the wet method. The dry storage estimate does not include costs for the new dry storage facility or fuel characterization. SNF storage costs include the storage costs of spent nuclear fuel for the first 100 years after a carrier is commissioned. We assumed the initial SNF cores would be removed at a carrier's midlife and sent to storage in its 25th year of service and remain there for 75 years and the replacement cores would be removed at the end of the carrier's service life and sent to storage near its 50th year of service and remain there for 50 years.

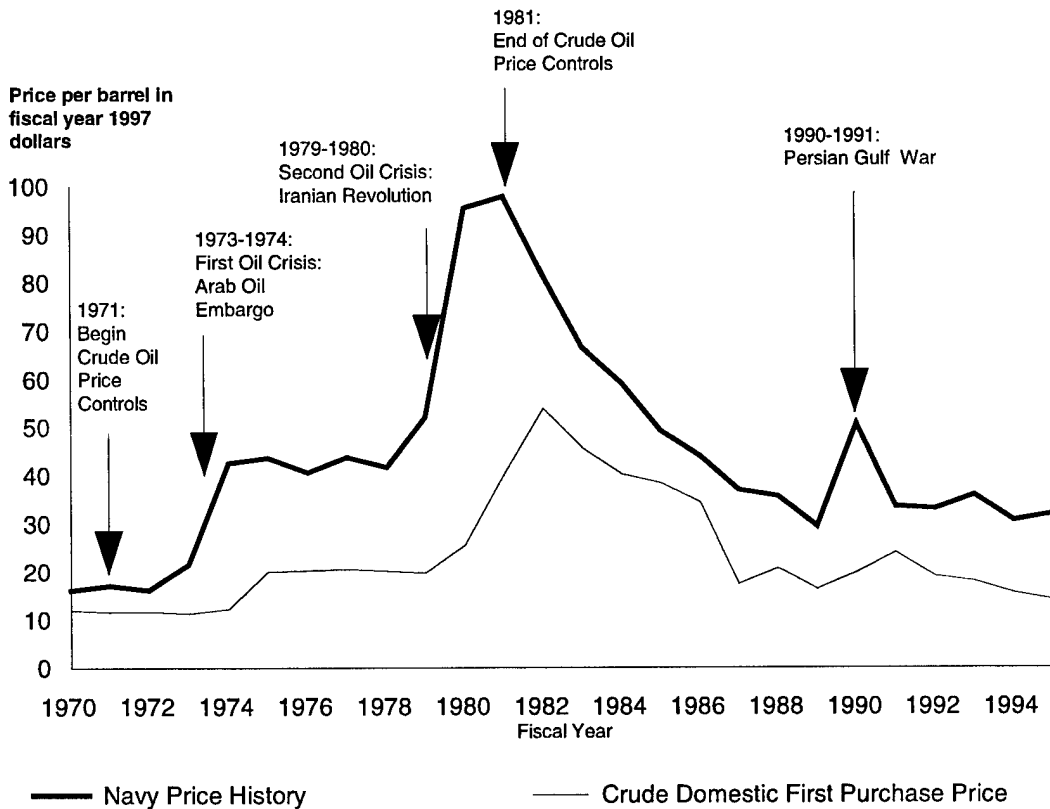
Effects of Pricing Alternatives for Fossil and Nuclear Fuel

The cost of fuel has been of interest throughout the debate over nuclear versus conventional propulsion. Because of the interest, we analyzed the affect of different pricing strategies on the cost of the conventional and nuclear carriers.

Fossil Fuel

Crude oil prices were fairly stable during the 1950s and 1960s. Prices rose significantly as a result of the oil crises of 1973 and 1979-80, although they did not remain at these peak levels. Figure I.1 shows the price of crude oil and the price the Navy paid for fossil fuel, as well as the major events affecting U.S. crude oil prices. Table I.1 shows the affect on life-cycle costs for a carrier if the cost of fossil fuel were double the current price.

Figure I.1: Crude Oil, Fossil Fuel, and Major Events Affecting U.S. Crude Oil Prices



Sources: Navy and Energy Information Administration.

The cost estimate of \$48 million for the uranium used in a Nimitz-class carrier over its lifetime was provided to us by the Navy. The estimate reflected the cost incurred by DOE when the uranium for the Navy was produced⁶ sometime during the late 1980s.

⁶Natural uranium undergoes a number of processes before it is a usable fuel: mining and milling, conversion, and enrichment. All domestic enrichment services were handled by the DOE until 1993, when these operations were transferred to the United States Enrichment Corporation.

Table I.1: Comparison of Life-Cycle Costs for the Conventionally Powered Carrier and the Nuclear-Powered Carrier Using Different Fuel Price Scenarios

Fiscal year 1997 dollars in millions				
	CV cost if fuel = \$29.52	CV cost if fuel = \$59.04	CVN cost if fuel = \$48 mil	CVN alternative fuel = \$101 mil
Investment	\$2,916	\$2,916	\$6,441	\$6,494
Direct operating and support				
Personnel	4,636	4,636	5,206	5,206
Fuel	738	1,476	0	0
Maintenance	4,130	4,130	5,746	5,746
Other	933	933	724	724
Indirect operating and support	688	688	4,290	4,290
Disposal	53	53	1,031	1,031
Life-cycle cost	\$14,094	\$14,831	\$23,438	\$23,492
Annual cost	\$282	\$297	\$469	\$470

Note: Numbers may not add due to rounding.

Source: Our analysis.

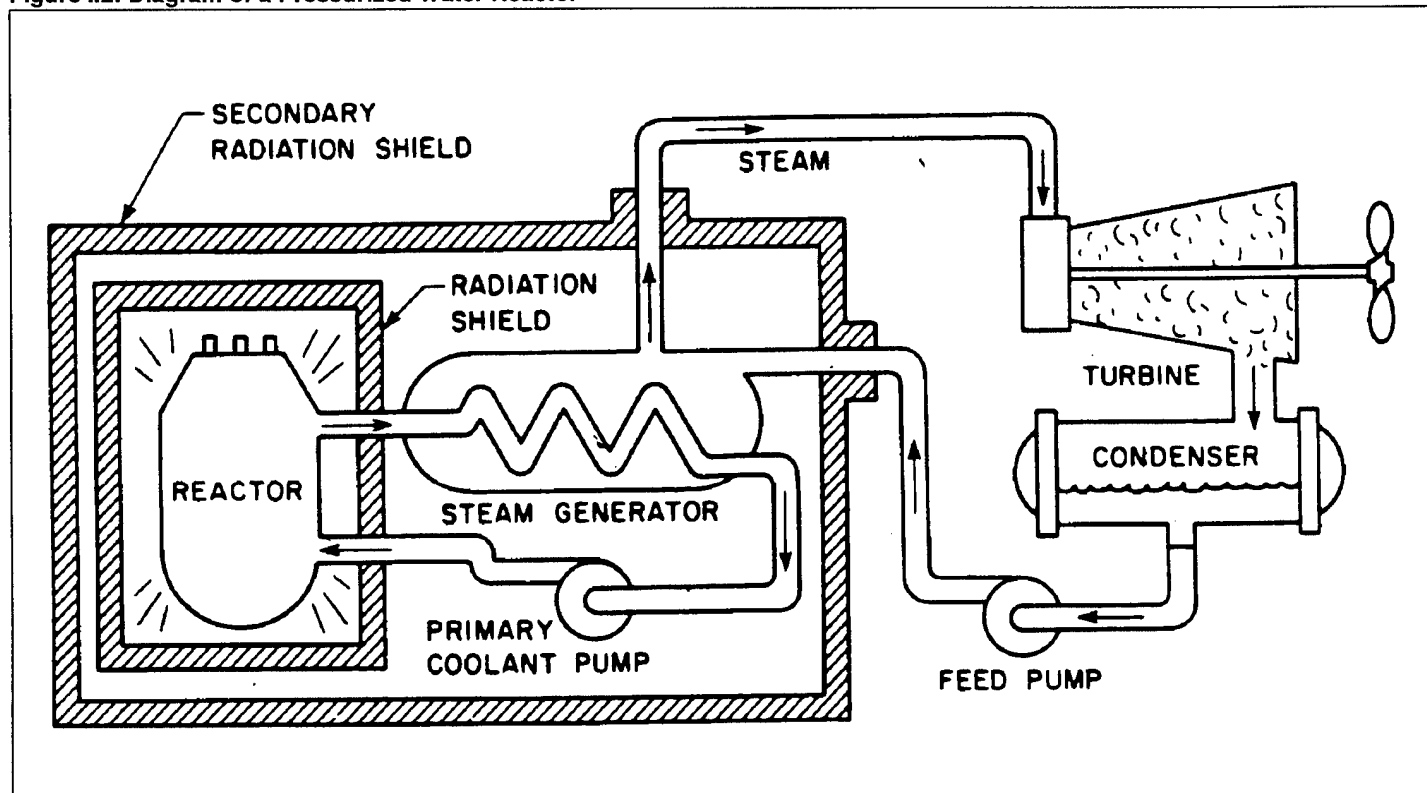
DOE stopped all production at its plants capable of producing defense-grade uranium⁷ in 1991 because there was a surplus of defense-grade uranium as a result of nuclear weapon agreements. Defense-grade uranium could be blended down to enrichment levels suitable for use in commercial reactors and sold to the private sector. The value of the uranium if sold and not used in a naval reactor is considered an opportunity cost. The uranium from one Nimitz-class carrier has an estimated market value, or opportunity cost, which is more than twice that of our estimate.

Methodology for Allocating Indirect Costs for Nuclear-Powered Ships Using a Demand for Power Factor

Naval propulsion plants use a pressurized water reactor design that has two systems: a primary system and a secondary system (see fig. I.2). The primary system circulates water in a closed loop consisting of the reactor vessel, piping, pumps, and steam generators. The heat produced in the reactor is transferred to the water. The heated water passes through the steam generators where it gives up its energy. The primary water is then pumped back to the reactor to be reheated.

⁷The difference between fuel used in commercial reactors and for naval reactors is the degree to which the uranium has been enriched. Commercial grade uranium is enriched to about 3-4 percent U-235 where defense grade uranium is enriched to above 90 percent. Uranium used to fuel a naval reactor is a defense grade uranium.

Figure I.2: Diagram of a Pressurized Water Reactor



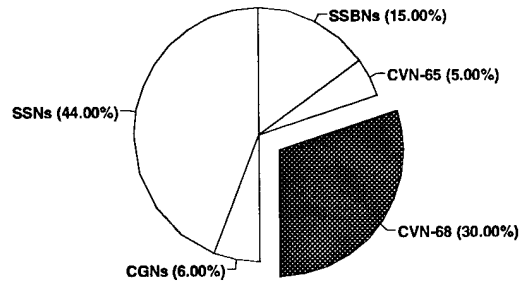
Source: Navy.

Nuclear and conventional propulsion systems of similar capacity have many common features. Both require heat to produce steam to drive turbines and generators. In the case of a nuclear system, the fissioning of uranium within the reactor replaces the burning of fossil fuel to generate the necessary heat. Inside a reactor, the uranium fuel is assembled in such a way that a controlled chain reaction can be achieved. Control rods can be inserted into or withdrawn from the reactor to create the necessary power level needed. Over time, the uranium is burned and eventually it must be replaced.

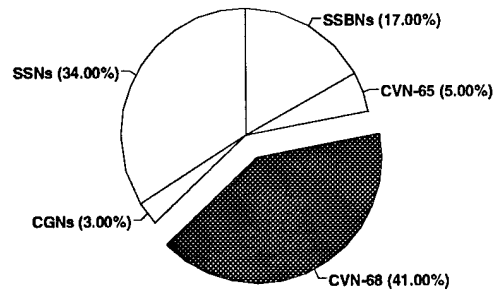
Size, weight, and operations influence a ship's demand for power as well as the propulsion plant and fuel that supply the power. For example, a Nimitz-class carrier, weighing nearly 100,000 tons, requires far more shaft

horsepower from its propulsion plant than is necessary for a submarine or surface ship that weighs about 8,000 tons. Similarly, there is a difference in the amount of nuclear fuel that is burned. We calculated the weighted average for each nuclear ship's demand for power, as measured by: shaft horsepower requirements and uranium burn. We found that one Nimitz-class carrier's demand for power is about equal to that of eight SSN-688s. As shown in figure I.3, in 1995, nuclear carriers accounted for about 35 percent of the nuclear power used by the fleet and are expected to account for nearly 60 percent by 2015 based on current force plans.

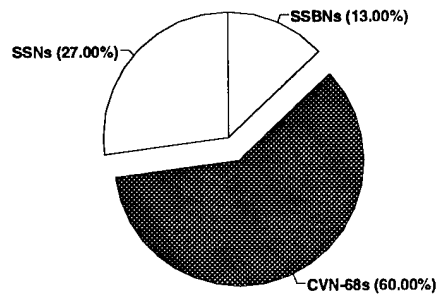
Figure I.3: Demand for Power by Nuclear-Powered Ships Based on Force Structures in Fiscal Years 1995, 2000, and 2015



Fiscal year 1995



Fiscal year 2000



Fiscal year 2015

Sources: Our analysis and Navy and Jane's Directory of Fighting Ships 1994-1995.

Present Value Analysis

Because investment alternatives normally incur different costs over different time streams it is our policy to compare the alternatives on an equal economic basis using a technique called present value analysis. This analysis, which converts costs occurring at different times to a common unit of measurement, is predicated on the theory that costs incurred in the future are worth less than costs incurred today. Present value analysis also provides a means to transform a stream of costs to a single number so it can be compared to another. Caution should be exercised when discounted dollars are used in performing analyses because discounted numbers are artificially small and can invite misinterpretation both in absolute amount and in comparing alternatives, especially in programs with very long time periods. A concern expressed about long duration projects is that normal discount rates virtually eliminate from consideration any values occurring beyond 25 years into the future. The expenditure streams in our analysis are about 60 years for the conventionally powered carrier and more than 100 years for the nuclear-powered carrier.

Our present value analysis used budgetary profiles we developed for each carrier type. The budget profiles included the major investment costs (initial acquisition, midlife modernization, inactivation, and disposal) as well as annual operating and support costs. The timing of the budget profiles was based on the assumption that both carriers would be commissioned in the same year and have 50-year service lives. The notional procurement profile of a nuclear carrier includes advance procurement of long lead nuclear components 2 years prior to full funding of the ship, and the construction period is estimated to be 1 year longer than for a conventional carrier. As a result, the nuclear-powered carrier's investment profile begins 3 years earlier than for a conventional carrier. We also used annualized operating and support costs. The budget profiles were then converted into projected outlay profiles using the Navy's official outlay rates.

While a performing present value analysis is a generally accepted practice, there is no generally agreed upon discount rate. However, there is agreement that a range of rates should be used to determine the investment's relative sensitivity to changes in rates. Our policy, in general, is to use the interest rate on marketable Treasury debt with maturity comparable to that of the program being evaluated (adjusted to reflect expected inflation when using constant dollars). We calculated the present value of the two carrier types using three different discount rates—our rate, the Office of Management and Budget rate, and the Congressional

Appendix I
Objectives, Scope, and Methodology

Budget Office rate. As table I.2 shows, regardless of the discount rate used, the nuclear carrier's present value was at least 57 percent more than the present value of the conventional carrier.

Table I.2: Discounted and Undiscounted Life-Cycle Costs for a Conventionally and Nuclear-Powered Carrier

Dollars in billions

Carrier option	Outlays	Our rate (4.43 ^a percent)	OMB rate (3.6 percent)	CBO rate (2.8 percent)
Conventional	\$14.1	\$4.9	\$5.8	\$6.9
Nuclear	22.2	8.2	9.5	11.1
Difference	\$8.1	\$3.3	\$3.7	\$4.2
Percent difference	57%	67%	64%	61%

Note 1: Numbers may not add due to rounding.

Note 2: CBO is Congressional Budget Office. OMB is Office of Management and Budget.

^aRate of return for 30-year treasury bonds minus the most recent estimate of inflation by Wharton Econometric Forecasting Associates.

Source: Our analysis.

Conventionally Versus Nuclear-Powered Cost-Effectiveness Debate—the Rationale for Nuclear Power

For fiscal year 1963, DOD requested a conventionally powered carrier. A prolonged debate to change the propulsion of the carrier, later named the U.S.S. John F. Kennedy (CV-67), to nuclear power, followed. The campaign to support nuclear power was led by the Chairman of the Joint Committee on Atomic Energy, the Secretary of the Navy, and the Chief of Naval Operations. Opposition to nuclear-powered carriers eventually weakened, and all aircraft carriers since have been nuclear-powered, beginning with the U.S.S. Nimitz (CVN-68) in the fiscal year 1967 program. Including the U.S.S. Enterprise (CVN-65), a total of eight nuclear-powered carriers have been built and two more are under construction.¹

In an April 1963 memorandum to the Secretary of Defense, the Secretary of the Navy concluded that “nuclear propulsion permits a significant increase in the beneficial military results for a given expenditure and that we must exploit and take maximum advantage of it. . .and that all new major warships should be nuclear-powered.” The Navy staff’s comparative analyses showed that the costs of a nuclear task force would be about the same as a nonnuclear task force with its fuel replenishment and escort ships. The advantages of nuclear propulsion in surface warships were summarized in an enclosure to the memorandum:

“As a nation with an overseas strategy, nuclear propulsion in our combatant surface ships adds an essential new dimension to their versatility and effectiveness in war or deterrence of war. Increased range and staying power, plus a reduction in vulnerability provided by nuclear propulsion, will make naval forces much stronger and more useful as instruments of national policy and power.”

The specific advantages accruing to nuclear propulsion, according to the Navy study, were

- virtually unlimited high-speed endurance;
- optimized prepositioning of (nuclear) fuel (the reactor cores reduce the quantity and total costs of conventional fuel which must be prepositioned and protected);
- reduced vulnerability to atomic fallout because nuclear-powered ships do not depend on a constant intake of large amounts of air for boilers;
- increased shipboard electric power for new radars, sonars, and missile systems that would otherwise reduce the operating range of conventionally powered ships; and
- elimination of stack gases.

¹The Harry S. Truman was commissioned in July 1998.

In the language of the memorandum the meaning of “virtually unlimited high-speed endurance” was elaborated

- Nuclear-powered forces can be sent at high sustained speeds to distant areas of operations and arrive ready to go into action—they do not have to refuel before engaging the enemy.
- Independent operations of nuclear ships can be conducted in those areas where simultaneous deployment of the usual replenishment forces may require an unacceptable amount of time or risk. The necessary logistic support ships can start later and/or transit more slowly and still arrive in time for replenishment of aviation fuel and ammunition.
- The requirement of oil-fueled forces to take into account the risk of loss of fuel oil facilities either at the source or en route to the refueling rendezvous is eliminated.
- Absence from the restrictions imposed by fueling requirements significantly reduces the vulnerability of the force by eliminating the requirement to slow down to conserve fuel and to refuel. These required refuelings reduce the tempo of any offensive and defensive effort.
- The nuclear-powered forces require less overall replenishment and have much greater freedom in the selection of location and time for the replenishment rendezvous. Nuclear propulsion also reduces the size of the logistic support force and its escorts.
- Nuclear-powered ships can be kept in an area of minimum vulnerability with respect to the enemy submarine threat until required to move into another action area. They can proceed at a high sustained speed using such indirect routes and circumvention to increase enemy submarine tasks as may be indicated by the overall tactical situation.

The Defense Secretary's February 1963 memorandum also asked the Navy to comment on specific topics. The Navy's comments regarding worldwide deployments, underway replenishments, future shipbuilding programs, and force structure reductions are summarized below.

- Worldwide Deployments
 - Nuclear propulsion will greatly facilitate fast initial reaction, rapid transit, readiness for combat on arrival, and strike group operations with reduced task group vulnerability and logistic support requirements.
 - The improved efficiency of coverage of potential trouble areas associated with nuclear-powered task groups can be capitalized on by either (1) better coverage, using the same numbers of groups as with conventional forces or (2) comparable coverage, using fewer groups.

- The potential exists to compensate for the increased costs of individual nuclear-powered ships by obtaining more effectiveness or by reducing force levels as these nuclear ships are delivered to the fleet.
- As they are delivered to the fleet, the nuclear-powered ships will be phased into those assignments where transit distances may be long and logistic support somewhat limited. For example, a nuclear-powered task group could perform a high speed transit of about 5,000 miles from 10 to 50 percent faster than a conventionally powered group, depending upon the level of fuel support received by the conventionally powered carrier groups.
- The costs of achieving this capability with a nuclear force would be approximately the same as with a nonnuclear force with its fuel replenishment and escort ships.
- Replenishment
 - Underway replenishment is the most reliable and effective method of restocking naval forces with large quantities of consumables in combat or in peacetime deployment to remote areas. This kind of support, however, cannot be relied on in armed conflict situations or in areas characterized by inadequate or nonexistent bases.
 - By eliminating the requirement for ship propulsion fuel, requirements for replenishment of aviation fuel and ordnance will become the controlling factors, varying directly with the level of aircraft activity and/or combat operations.
 - Design and operational evaluations will continue to be directed toward minimizing dependence on nuclear-powered ships upon logistic support by increasing consumables storage, such as was done in the case of the CVAN-67 design for aviation fuel and ordnance.
- Future shipbuilding programs
 - The application of nuclear propulsion is toward a goal of all nuclear attack carrier groups. The greatest advantages of nuclear power accrue when the entire task group is so equipped. However, the advantages to screen ships themselves are significant. An alternative would be to use a nuclear-powered carrier with a conventional screen; however, in this case, the operational and logistics gains will be less if the nuclear-powered carrier must function as a part-time oiler and is still tied to the logistics of her escorts.
- Force reductions
 - Nuclear-powered task groups will provide improved efficiency of coverage of potential trouble areas. The benefits thereby can be capitalized on, in part, by a reduction in carrier task groups or by increased effectiveness.

Appendix II
Conventionally Versus Nuclear-Powered
Cost-Effectiveness Debate—the Rationale
for Nuclear Power

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- A general transition to nuclear propulsion should permit some reduction in total numbers of ships required to meet the Navy's widespread, worldwide commitments.

Underway Replenishment Extends the Endurance of Carriers

The Navy operates a Combat Logistics Force fleet of about 40 ships that resupply combatant ships at sea with several commodities. The ships carry significant amounts of these commodities, for example, ship and aviation fuel (DFM and JP-5, respectively), ordnance, and other supplies such as ship and aircraft fuel, ordnance, and food (see table III.1), which enables combatant ships to operate at sea almost indefinitely, if required, without ever needing to go into ports to replenish their stocks. The force represents additional days of sustainability for the naval force by serving as an extension of the combatant ships' bunkers, magazine and store rooms.

Table III.1: Capacities of Selected Combat Logistics Force Ships

Class	Speed	Fuel ^a	Ordnance	Other supplies
	(knots)	(barrels)	(tons)	(tons)
(T-) AE-26	20	^b	6,000	^b
(T-) AFS-1	20	18,000	^c	7,000
AO-177	20	150,000	625	420
(T-) AO-187	20	180,000	^c	^d
AOE-1	30	177,000	2,500	750
AOE-6	30	156,000	1,800	650

Note: T-class Combat Logistics Force ships are operated by the Navy's Military Sealift Command. These ships use civilian, instead of military, crews but may have a small military detachment aboard. A majority of the non-AOE class ships are now operated by the Military Sealift Command.

^aReflects a combined total for DFM and JP-5.

^bPrimary mission is ordnance replenishment. Limited quantities of fuel and other supplies are also available.

^cNo ordnance carried.

^dPrimary mission is fuel replenishment. Limited capacity to carry other supplies.

Source: Navy.

A comparison of these capacities with average daily ship and aviation fuel consumption and ordnance expenditures reflected in table III.2 shows that daily fuel consumption represents only a small percentage of the fuel capacity carried by Combat Logistics Force ships.

Appendix III
Underway Replenishment Extends the
Endurance of Carriers

Table III.2: Average Daily Fuel and Ordnance Consumption Rates for Selected Ship Classes

Ship class	DFM (barrels)	JP-5 (barrels)	Ordnance (tons)
Carrier (CV)	2,700	6,500	70-150
Carrier (CVN)	^a	6,500	70-150
CG-47	725	^a	^a
DD-963	710	^a	^a
DDG-51	710	^a	^a

^aNo quantities shown.

Source: Center for Naval Analyses report.¹

The conventionally powered cruisers and destroyers that are a part of carrier battle groups are dependent on underway replenishment support by Combat Logistics Force. Compared to a conventional carrier, they have smaller fuel storage capacities and relatively high fuel consumption rates at higher speeds. Table III.3 compares the approximate range and endurance of these ships as well as of a conventional carrier.

¹Center for Naval Analyses Report 205, Sizing the Combat Logistic Force, June 1993. The Center for Naval Analyses used 1990 and 1991 fleet data contained in the Navy Energy Usage Reporting System for fuel consumption, and aircraft fuel and ordnance consumption based on the final days of Operation Desert Storm.

Appendix III
Underway Replenishment Extends the
Endurance of Carriers

Table III.3: Battle Group Ship Range and Endurance at Various Speeds

Speed (knots)	18	22	26	30
CV				
Range (nm)	8,600	7,800	6,300	5,100
Daily fuel consumption (percentage of total load)	5	7	10	14
Days endurance	20	15	10	7
CG-47				
Range (nm)	6,200	5,600	4,600	3,300
Daily fuel consumption (percentage of total load)	7	9	14	22
Days endurance	14	11	7	5
DD-963				
Range (nm)	5,100	4,800	4,200	3,300
Daily fuel consumption (percentage of total load)	8	11	15	22
Days endurance	12	9	7	5
DDG-51				
Range (nm)	4,300	4,000	3,500	2,800
Daily fuel consumption (percentage of total load)	10	13	18	26
Days endurance	10	8	6	4

Note: Ranges rounded to nearest 100 nautical miles. Fuel consumption and days endurance rounded to nearest whole number.

Source: Our analysis of Navy data.

As shown in table III.4, the other ships in the battle group require a higher proportion of the fuel during a transit than a conventional carrier requires. Thus, from a practical standpoint, the time penalty for refueling is more associated with the rest of the battle group than with the conventional carrier.

Appendix III
Underway Replenishment Extends the
Endurance of Carriers

Table III.4: Battle Group Propulsion
Fuel Underway Replenishment
Requirements During Transits

Transit distance (nm)	Transit speed	Total (barrels)	Underway replenishment requirement	
			Percent of total	
			CV	Remainder of battle group ^a
4,800—Norfolk, Va. to the Eastern Mediterranean Sea				
	20	52,370	0	100
	24	91,953	43	57
	28	106,286	37	63
8,600—Norfolk, Va. to the Persian Gulf via the Suez Canal				
	20	158,656	25	75
	24	158,656	25	75
	28	236,276	34	66
12,000—San Diego, Calif. to the Persian Gulf				
	20	229,564	34	66
	24	250,609	32	68
	28	342,562	35	65

^a For this analysis, we used a battle group configuration that included one conventional carrier, two CG-47 class cruisers, two DD-963 class destroyers, and two DDG-51 class guided missile destroyers. This configuration is consistent with the Navy's standard carrier battle group. We also assumed that underway replenishments would occur when the ships' fuel levels reached 30 percent of capacity and that the ships were then refueled to full capacity.

Source: Our analysis of Navy data.

The presence of a station ship² in the battle group extends the group's range considerably compared to those shown in table III.3. Table III.5 reflects an AOE's impact on the ability of notional conventional (CVBG) and nuclear (CVN BG) carrier battle groups to reach their destinations. As in the previous analyses, these battle groups consist of a carrier (CV or CVN), two CG-47s, two DD-963s, two DDG-51s, and one AOE-1. As the table shows, the capabilities of the two groups are about equal.

²Station ships travel with carrier battle groups. They carry petroleum products, ordnance, and other supplies and are generally replenished by shuttle ships operating from land-based facilities worldwide.

Appendix III
Underway Replenishment Extends the
Endurance of Carriers

Table III.5: Battle Group Comparative Transit Capabilities With AOE Support (illustrative transit destinations and distances)

Transit distance (nm)	Transit speed	CV ^a	CVN ^a
4,800—Norfolk, Va., to the Eastern Mediterranean Sea			
	20	Yes	Yes
	24	Yes	Yes
	28	Yes	Yes
8,600—Norfolk, Va., to the Persian Gulf via the Suez Canal			
	20	Yes	Yes
	24	No	Yes
	28	No	No
12,000—San Diego, Calif., to the Persian Gulf			
	20	No	No
	24	No	No
	28	No	No

^aA "Yes" indicates that the battle group completes the transit with at least 30 percent propulsion fuel remaining, collectively.

Source: Our analysis of Navy data.

To further illustrate the information presented in table III.5, we compared the estimated remaining fuel levels of these battle groups when they reached their destinations, assuming that the battle groups sailed at a constant speed of 20 knots. We assumed that the ships would be fully refueled whenever they reached 30 percent of their fuel capacities. We also assumed that the diesel fuel marine (DFM) carried by AOE's represented 60 percent of their total fuel capacity.

For example, the distance from Norfolk to the Eastern Mediterranean Sea is approximately 4,800 nautical miles and could be covered in about 10 days. The conventional carrier would have arrived with over 40 percent of fuel remaining and would not have needed refueling during the transit. The carrier could steam another 2 days at a constant 20 knots before reaching 30 percent of capacity (consuming about 6 percent of capacity per day). Once refueled the carrier could operate about another 12 days at a constant 20 knots before again reaching 30 percent. The destroyer and cruiser escorts of both battle groups would arrive with between 53 and 90 percent of their fuel remaining, depending on the type of ship and interval since their last at-sea refueling. The AOE supporting each battle group would have about 54,000 barrels of ship fuel remaining when

arriving on station, if no other Combat Logistics Force support was provided.

In another instance, the distance from Norfolk to the Persian Gulf is approximately 8,600 nautical miles and could be covered in about 18 days. The conventional carrier would arrive in the Persian Gulf with about 65 percent of its fuel remaining, having been refueled once during the voyage. We estimated that the carrier could operate another 6 days at 20 knots before reaching 30 percent fuel remaining. The AOE would have enough capacity to refuel the DDG-51s twice but could only refuel the CG-47s and DD-963s once, if not refueled itself during the voyage. The DDG-51s would arrive in the Persian Gulf with about 80 percent fuel remaining, while the CG-47s would have about 30 percent fuel remaining. The DD-963s would not be able to reach the Persian Gulf. In this case, either the AOE would need to be refueled or another oiler, such as a T-AO-187, would need to accompany the battle group. In the latter case, all combatant ships would reach the Persian Gulf with over 60 percent fuel on board, and the oilers would have over 55,000 barrels remaining. On this voyage, the carrier would require about 25 percent of the replenishment fuel, while the escorts would require the remainder. The CG-47s and the DDG-51s in a nuclear carrier battle group would arrive at nearly full fuel capacity, having been replenished two and three times, respectively, while the DD-963s would have about 65 percent fuel remaining. The AOE, however, would essentially be empty. We believe that on a voyage of this distance, either the AOE would be replenished itself at some point or another oiler would accompany the battle group.

Additionally, the distance from San Diego to the Persian Gulf is about 12,000 nautical miles and could be covered in about 25 days at a sustained speed of 20 knots. With the refueling support of one AOE and no additional Combat Logistics Force ships, only the carrier in the conventional battle group would reach the Persian Gulf. It would have about 25 percent fuel remaining. None of the conventional battle group's escorts would reach the Gulf. In the case of the nuclear carrier battle group, the CG-47s would arrive with about 40 percent fuel remaining, and the DDG-51s would have about 15 percent fuel remaining. The DD-963s would run out of fuel before reaching the Gulf. A voyage of this distance would most likely require additional Combat Logistics Force support. If another oiler, such as a T-AO-187, accompanies each battle group, all the ships of both battle groups reach the Persian Gulf with no additional support provided. The conventional carrier would arrive with about 70 percent fuel remaining, while the escorts would have from about 40 to

Appendix III
Underway Replenishment Extends the
Endurance of Carriers

85 percent fuel remaining. The conventional battle group's two oilers, however, would essentially be out of fuel, unless they were resupplied during the voyage. In this example, the conventional carrier required about 35 percent of the battle group's overall underway refueling requirement. In the nuclear carrier battle group, the escorts would also have between 40 and 85 percent of their fuel remaining, and the two oilers would have about 65,000 barrels remaining.

Comparison of the Transit Time of Conventionally and Nuclear-Powered Carriers Responding to Selected Crises

We examined the movement of carriers that responded to several crisis situations in this decade to compare the transit times of conventionally and nuclear-powered ships. The crises examined were Iraq's invasion of Kuwait in 1990, U.N. operations in Somalia in 1993, threatening Iraqi troop movements toward Kuwait in 1994, and operations in Bosnia in 1995. We also examined the transits of carriers responding to the crisis caused by Iraq's violation of the "no-fly-zone" over southern Iraq in October 1997 and actions taken in January 1998 to maintain a two-carrier presence in the Persian Gulf.

Operations Desert Shield/Desert Storm

When Iraq invaded Kuwait on August 2, 1990, the nuclear-powered U.S.S. Eisenhower (CVN-69) was in port in Naples, Italy. The carrier traveled about 1,040 nautical miles to Port Said, Egypt, from August 3-7, a period of 5 days, and later moved through the Suez Canal into the Red Sea. The conventional powered U.S.S. Independence (CV-62) was operating near Diego Garcia in the Indian Ocean when the invasion began. The Independence arrived in the Gulf of Oman on August 5th, covering about 2,200 nautical miles in 3 to 4 days. Considering the time taken to travel this distance, the Independence would probably have made the voyage at a sustained speed of between 24 and 32 knots.

Table IV.1 summarizes the transit times of six other carriers that sailed from ports in the United States and Japan and participated in Desert Storm.

**Appendix IV
Comparison of the Transit Time of
Conventionally and Nuclear-Powered
Carriers Responding to Selected Crises**

Table IV.1: Steaming Time/Speed of Carriers Deploying to Desert Shield/Storm

Carrier	Depart		Arrive		Distance	Days		Net speed ^a	Remarks
	From	Date	At	Date		Elapsed	Underway		
Midway (CV-41)	Yokosuka, Japan	10/02/90	Gulf of Oman	11/01/90	6,495	30	24	11.3	3-day port visits at Subic Bay and at Singapore
Saratoga (CV-60)	Mayport, Fla.	08/07/90	Red Sea	08/22/90	5,867	15	14	17.5	Assumes a 1-day delay to transit Suez Canal
Rangers (CV-61)	San Diego, Calif.	12/08/90	Strait of Hormuz	01/15/91	11,666	38	33	14.7	5-day port visit at Subic Bay; assumes no other stops in route
America (CV-66)	Norfolk, Va.	12/28/90	Red Sea	01/15/91	5,527	18	17	13.5	Assumes a 1-day delay to transit Suez Canal
	Red Sea	02/07/91	Persian Gulf	02/14/91	3,450	7	7	21.1	
Kennedy (CV-67)	Norfolk, Va.	08/15/90	Red Sea	09/14/90	5,527	30	27	8.5 ^b	2-day port visit to Alexandria, Egypt, also assumes a 1-day delay to transit Suez Canal
Roosevelt (CVN-71)	Norfolk, Va.	12/28/90	Red Sea	01/14/91	5,527	17	16	14.4	Assumes a 1-day delay to transit Suez Canal
	Red Sea	01/14/91	Persian Gulf	01/21/91	3,540	7	7	21.1	

^aNet steaming speed was derived from the total elapsed days minus days spent in port and/or awaiting to transit the Suez Canal, multiplied by 24 (hours), divided into the distance.

^bThe Kennedy spent about 7 days in the Virginia Capes operating area conducting battle group training and carrier landing qualifications before proceeding eastward. If this time is not counted as days underway toward the Red Sea, then the ship's transit speed was 11.5 knots.

Source: Our analysis of Navy data.

Comparison of the Voyages of the Lincoln and the America Supporting U.N. Operations In Somalia (1993)

The U.S.S. Abraham Lincoln (CVN-72) operating in the Persian Gulf supporting Operation Southern Watch was ordered to move to the coast of Somalia to support U.N. operations on October 7, 1993. The Lincoln moved through the Straits of Hormuz on October 8 and arrived off the coast of Mogadishu, Somalia, 4 days later, on October 12th. We estimate that the Lincoln would have traveled at a sustained speed of 19 knots to cover the approximately 1,800 nautical miles from the Straits of Hormuz to Somalia in 4 days. The Lincoln operated off the coast of Somalia until November 4, 1993.

The U.S.S. America (CV-66) was operating in the Adriatic Sea supporting U.N. peacekeeping operations in Bosnia-Herzegovina, when ordered on October 27, 1993, to relieve the Lincoln operating off the coast of Somalia. The America traveled from the Adriatic Sea to the Mediterranean Sea entrance to the Suez Canal, in about 2 days, covering a distance of about 1,040 nautical miles, which equated to a sustained speed of about 22 knots. The America completed the Suez Canal transit on October 30th and reached the coast of Somalia on November 4th. We estimate that if the America traveled about 2,400 nautical miles from the Suez Canal to the coast of Somalia in about 5 days, it could have done so at a sustained speed of about 20 knots. We estimate that the America would have completed the total trip with about 60 percent of its propulsion fuel remaining if no refueling had taken place.

Comparison of the Transit of the Washington in October 1994, and a Transit of Similar Length by America in December 1995

When Iraq moved two divisions of the Republican Guard south of the Euphrates River, toward Kuwait, in early October 1994, the President, faced with the imminent possibility of another Iraqi invasion of Kuwait, directed that U.S. forces be dispatched to the region. This effort was called Operation Vigilant Warrior. Included among those forces was the U.S.S. George Washington (CVN-73), the closest American aircraft carrier to the Middle East, operating in the Adriatic Sea. Two other carriers were also deployed at sea at that time but were much farther away; the U.S.S. America (CV-66) was operating near Haiti, and the U.S.S. Kitty Hawk (CV-63) was operating near Korea.

The George Washington battle group was ordered to move to the Persian Gulf on the evening of October 7, 1994, and arrived in the Red Sea on October 10th.¹ The George Washington, with one escort, continued to

¹Once in the Red Sea, attack aircraft from the U.S.S. George Washington, or any other carrier, could have reached targets in southern Iraq with refueling by aerial tankers. Also, on October 10th, Saddam Hussein announced that the Republican Guard divisions would withdraw, and they began to move northward soon afterwards.

proceed around the Arabian Peninsula, arriving in the Persian Gulf on October 14th.² According to a Center for Naval Analyses study,³ the George Washington averaged about 25.6 knots, excluding the time spent waiting to transit the Suez Canal and actually transiting the canal.

By comparison, the U.S.S. America made a similar voyage, but in the opposite direction, from the Persian Gulf to the Adriatic Sea in December 1995. The America began the voyage on December 2nd, transited the Suez Canal on December 9th, and was in position in the Adriatic Sea on December 11, 1995, in time for the signing of the peace agreement between the fighting Balkan factions. Assuming that this voyage took 8 full steaming days, excluding the time associated with transiting the Suez Canal, the America would have covered the nearly 4,200 nautical miles at a sustained speed of about 22 knots. If the America had steamed at the same sustained speed (26 knots) as the George Washington did during Vigilant Warrior, a speed within its capability, it would have arrived with about 33 percent fuel remaining if there was no refueling during the voyage. With one refueling, the U.S.S. America would have taken about 2 hours longer than the George Washington to cover the same distance but would have arrived with full fuel tanks.

Comparison of the Transit of the Nimitz in October 1997, and a Similar Transit by the Independence in January/ February 1998

On October 1, 1997, after Iraqi aircraft had violated the southern "no-fly-zone," the U.S.S. Nimitz (CVN-68) was ordered to proceed to the Persian Gulf at best speed. The carrier had completed a port visit to Hong Kong and was scheduled to visit Singapore before heading for the Persian Gulf. According to the Navy, the Nimitz completed this 5,500 nautical mile transit in 11 days at an average speed of advance of about 21 knots. Our review of transit data indicated the carrier spent about 39 percent of the voyage at 27 knots and above. The carrier's longest sustained steaming period at or above 27 knots was one 9-hour period. The Navy reported that the Nimitz was able to conduct flight operations on 6 of the 11 transit days. The carrier arrived in the Persian Gulf on October 11, 1997.

²Several dozen Air Force tactical aircraft arrived in the theater about the same time as did the U.S.S. George Washington. On October 8th, Air Force units at Langley Air Force Base, Virginia, and Pope Air Force Base, North Carolina, were alerted to deploy, but their aircraft were held at their bases pending final basing arrangements with Saudi Arabia. The Langley fighters arrived in Saudi Arabia on October 11th, while the Pope aircraft arrived on October 13th and 15th, after completing approximately 17-hour flights.

³Exploring Alternative Paths for Future Sea-Based TACAIR Platforms, Report CAB 95-62, July 1995.

**Appendix IV
Comparison of the Transit Time of
Conventionally and Nuclear-Powered
Carriers Responding to Selected Crises**

On January 23, 1998, the U.S.S. Independence (CV-62) was ordered to transit from Japan to the Persian Gulf to replace the Nimitz, which was scheduled to return to the U.S. for a scheduled comprehensive refueling overhaul. Our analysis of transit data for the Independence indicated the carrier averaged over 24 knots during the voyage and spent over 70 percent of the time at 27 knots and above. During various parts of the transit, the ship sustained speeds of 27 knots and above for several lengthy periods of time, including 42, 31, and 27 continuous hours. Our review of transit data indicated that aircraft flew on at least 5 days of the transit, the last period ending late in the evening of February 4, 1998, the night before the ship entered the Persian Gulf. The ship slowed down to speeds of 14 knots or less to conduct fuel replenishments and make periodic course and speed changes to conduct flight operations.

Operations of Carriers in the Persian Gulf War

An October 1995 report on the Naval Nuclear Propulsion Program Classification Review included a discussion of the impact of nuclear propulsion in the Gulf War. The report stated:

"During this war the U.S. had unchallenged use of the oceans. Over 85 percent of the war supplies were transported by ocean, halfway around the world. Accomplishing this required complete control of the sea. A few enemy nuclear-powered submarines could have significantly disrupted our supply lines. Nuclear-powered submarines with their covert capability provided platforms for launching cruise missile strikes without concern for detection prior to launch. The nuclear-powered aircraft carriers provided U.S. Commanders with platforms for aircraft strikes that could be located for sustained periods in areas of the Middle East not available by land. If Iraq had obtained access to nuclear propulsion technology and had developed nuclear-powered submarines, it would have significantly impacted the course of the war."

Our analysis of carrier operations and support during Operation Desert Storm did not reveal any significant differences between the nuclear-powered carrier U.S.S. Theodore Roosevelt (CVN-71) and five conventionally powered carriers, including the World War II-vintage U.S.S. Midway (CV-41), that could be attributed to nuclear propulsion. Although aircraft from the Roosevelt flew more missions than any other Desert Storm carrier, this was due to several factors independent of the propulsion system, including the distance to targets and the number and mix of aircraft aboard each carrier. When the number of assigned aircraft is considered, the number of sorties generated by each carrier is almost identical.

Our analysis also indicated that the Navy supported all six carriers in essentially the same manner. Despite the nuclear carrier's greater jet fuel and ordnance capacity, and its reduced reliance on logistics support, the Roosevelt did not operate for longer intervals between replenishment actions than the conventional carriers. Instead, all of the carriers were replenished at about the same frequency, well before fuel and ordnance reached critical levels.

Missions Generated by Each Carrier Were Comparable for the Regions in Which They Operated

When Operation Desert Storm began on January 17, 1991, the Navy had three conventional carriers, U.S.S. America (CV-66), U.S.S. John F. Kennedy (CV-67), and U.S.S. Saratoga (CV-60), positioned in the Red Sea and two conventional carriers, U.S.S. Midway (CV-41) and U.S.S. Ranger (CV-61), in the Persian Gulf. The nuclear-powered U.S.S. Theodore Roosevelt (CVN-71), sailing from the Red Sea to the Persian Gulf when hostilities began, did not begin to strike targets until

January 22nd. The Navy operated three carriers each in the Red Sea and Persian Gulf for about 3 weeks until the America moved to the Persian Gulf in mid-February 1991, shifting the number of carriers in each operating area to two and four ships, respectively.

Navy fixed-wing carrier-based aircraft flew over 18,000 sorties during the war, according to statistics developed by Center for Naval Analyses in an analysis of Desert Storm carrier operations. Aircraft from the Red Sea Battle Force flew nearly 6,200 sorties (one-third of the sorties), while aircraft from the Persian Gulf Battle Force flew nearly 11,800 sorties. We believe that the significant differences in the operations of the two battle forces were largely driven by the ranges to their targets. The Red Sea carriers were about 400 to 600 nautical miles away from their targets. Their aircraft had to fly even greater distances to get to and from aerial tanker positions and to use specific entry and exit corridors to reach the targets. The Persian Gulf carriers, on the other hand, launched many missions to the coastal region and were generally closer to their targets than the Red Sea carriers. As a result, the Persian Gulf carriers generally launched more sorties of shorter duration. As the war progressed, the Persian Gulf carriers moved further north in the Gulf, reducing strike ranges even more. The shorter distances allowed the carriers to shift into cyclic operations and generate many more sorties in the same span of time. In addition, the America's move to the Persian Gulf increased the number of carriers to four and added further to the total sorties generated by those carriers.

Because of the extended ranges involved during attacks on Iraq, carrier-based aircraft required refueling from land-based tankers. Aircraft from the Red Sea carriers relied on land-based tankers for the duration of the war. In the Persian Gulf, the carriers were initially positioned about 280 nautical miles southeast of Kuwait City. As the war progressed and the threat of Iraqi air and missile attacks on the Persian Gulf carriers diminished, the carriers moved farther north, reducing their dependence on land-based tankers. By the start of the ground war in late February, the carriers were positioned about 185 nautical miles southeast of Kuwait City. After the carriers' arrival in the northernmost operating areas, Navy refueling aircraft provided all refueling for Persian Gulf naval air strikes.

The total sorties generated by each carrier, as well as the average number of sorties flown during the war, are shown in table V.1. The Kennedy and the Saratoga operated in the Red Sea during the entire period, while the Midway, the Ranger, and the Roosevelt operated in the Persian Gulf. The

America began the war in the Red Sea but moved to the Persian Gulf in mid-February for the final stages of the war.

Table V.1: Average Sorties Per Day Per Carrier During Desert Storm (43 Days)

	Midway (CV-41)	Saratoga (CV-60)	Ranger (CV9-61)	America (CV-66)	Kennedy (CV-67)	Roosevelt (CV-71)	Total
Total sorties	3,019	2,374	3,329	2,672	2,574	4,149	18,117
Daily average	70.2	55.2	77.4	62.1	59.9	96.5	421.3

Source: Our analysis of Center for Naval Analyses data.

Number of Sorties Generated by Individual Carriers Were Proportional to the Size of Their Air Wings

The number of aircraft assigned to each carrier varied considerably and had a direct impact on the sorties generated by each carrier. When the average number of sorties per assigned aircraft are compared, there is little difference between carriers operating in the same area (see table V.2). Although the U.S.S. Theodore Roosevelt (CVN-71) launched the most sorties of any carrier (4,149), the ship, along with the U.S.S. John F. Kennedy (CV-67), had the most aircraft assigned—78 aboard each carrier. Since the Roosevelt operated in the Persian Gulf, considerably closer to assigned targets than the Kennedy in the Red Sea, it was able to generate more sorties. On the other end of the spectrum, the World War II-vintage U.S.S. Midway (CV-41) had only 56 aircraft assigned (nearly 30 percent less than the Roosevelt), the least of any carrier, followed by the U.S.S. Ranger (CV-61) with 62 aircraft.

When sorties are compared based on the number of aircraft assigned, the sortie generation rates are nearly identical between the carriers. The significant differences are between the Red Sea and Persian Gulf carriers. When carriers in the same region are compared, their sortie generation rates are also almost identical. The Kennedy and the U.S.S. Saratoga (CV-60), which operated in the Red Sea for all of Desert Storm, each averaged 33 sorties per aircraft. The three full-time Persian Gulf carriers, Midway, Ranger, and Roosevelt, each averaged about 53 sorties per aircraft.

Appendix V
Operations of Carriers in the Persian Gulf
War

Table V.2: Comparison of the Average Number of Sorties Generated by Each Carrier

	Midway (CV-41)	Saratoga (CV-60)	Ranger (CV-61)	America (CV-66)	Kennedy (CV-67)	Roosevelt (CVN-71)	Total
Total sorties	3,019	2,374	3,329	2,672	2,574	4,149	18,117
Aircraft assigned:							
F-14	0	20	20	20	20	20	100
F/A-18	30	18	0	18	0	19	85
A-6E	14	14	22	14	13	18	95
A-7	0	0	0	0	24	0	24
E-2	4	4	4	4	5	4	25
EA-6B	4	4	4	5	5	5	27
KA-6D	4	4	4	4	3	4	23
S-3B	0	8	8	8	8	8	40
Total	56	72	62	73	78	78	419
Average sorties per aircraft	53.9	33.0	53.7	36.6	33.0	53.2	43.2

Source: Our analysis of Center for Naval Analyses data.

Carriers Operated on a Rotating Basis

Although Navy aircraft flew sorties every day throughout Desert Storm, none of the carriers operated around-the-clock. Instead, they rotated on an operating schedule that enabled them to have intervals of off-duty time. According to the Center for Naval Analyses data, the three carriers initially operating in the Red Sea, the U.S.S. America (CV-66), the U.S.S. John F. Kennedy (CV-67), and the U.S.S. Saratoga (CV-60), followed a rotating schedule with two carriers conducting flight operations while the third stood down for 2 days. When the America departed for the Persian Gulf on February 7th, the remaining two carriers continued to operate with periodic stand-down intervals. In the Persian Gulf, the U.S.S. Midway (CV-41), the U.S.S. Ranger (CV-61), and the U.S.S. Theodore Roosevelt (CVN-71) also followed a rotating operating schedule. Each carrier conducted air operations for approximately 15 hours during a 24-hour interval. During the remaining 9 hours of a 24-hour interval, one carrier suspended air operations. The Ranger's and Roosevelt's on-duty periods occurred during opposite portions of the 24-hour interval—with 3 hours of concurrent operations during turnovers. The Midway's on-duty period was roughly centered on one of Ranger's and Roosevelt's turnovers. The Center for Naval Analyses reported that there were only 6 days during the war when all six carriers operated. The rest of the time usually four or five carriers were on line while others stood down.

Average Sorties Per Operating Day Were Not Significantly Different Among the Carriers

When daily sortie rates were based on the number of days each carrier operated, there was a significant increase in average sorties. As shown in table V.3, the U.S.S. Theodore Roosevelt (CVN-71) led all carriers, averaging about 106 sorties per day. The smallest and oldest carrier, the U.S.S. Midway (CV-41), averaged about 89 sorties, 17 less than the Roosevelt, but did so with 22 fewer aircraft. When we factored in the number of assigned aircraft to average number of sorties per operating day, the Midway led all carriers. The Midway averaged 1.59 sorties per aircraft per operating day, followed by the U.S.S. Ranger (CV-61) with an average of 1.41 sorties, and the Roosevelt with 1.36 sorties.

Table V.3: Average Sorties Per Operating Day Generated by Each Carrier

	Midway (CV-41)	Saratoga (CV-60)	Ranger (CV-61)	America (CV-66)	Kennedy (CV-67)	Roosevelt (CVN-71)
Total sorties	3,019	2,374	3,329	2,672	2,574	4,149
Aircraft assigned	56	72	62	73	78	78
Operating days	34	33	38	31	31	39
Average sorties per operating day	88.8	71.9	87.6	86.2	83.0	106.4
Average operating day sorties per aircraft	1.59	1.00	1.41	1.18	1.07	1.36

Source: Our analysis of Center for Naval Analyses data.

Logistics Support Was Comparable for All Carriers

The Navy committed about 40 percent of its Combat Logistics Force ships—combat stores ships, oilers, ammunition supply ships, and multicommodity fast combat support ships—to Desert Storm. Each of the carrier battle groups was assigned its own dedicated support ships, to the extent possible, that remained on station with its battle group and enabled frequent replenishment of fuel and ordnance. According to Center for Naval Analyses, all carriers were replenished at about the same frequency, approximately every 3 to 3-1/2 days. The Center for Naval Analyses concluded that the increased capacity for ordnance and aviation fuel in the nuclear design was not sufficient to untether the battle force from the logistics pipeline. It also concluded that the hoped for increase in freedom of operational employment for nuclear carriers was restricted by the fossil fuel dependence of their accompanying surface combatants.

Fuel Replenishment During Desert Storm Was Comparable for Nuclear- and Conventionally Powered Carriers

According to the Center for Naval Analyses, which published several studies related to Desert Storm, the frequency that aviation fuel was replenished was essentially the same for all carriers, including the U.S.S. Theodore Roosevelt (CVN-71), even though nuclear-powered carriers have about 1.7 million more gallons of aviation fuel storage capacity. Table V.4 shows that aviation fuel was replenished about every 3 days for the carriers operating in the Persian Gulf.

Table V.4: Frequency of Aviation Fuel Replenishment by Persian Gulf Carriers During January and February 1991

	Midway (CV-41)	Ranger (CV-61)	America (CV-66)	Roosevelt (CVN-71)
Number of replenishments	19	41	6	12
Days in Persian Gulf	59	46	16	40
Replenishment frequency (days)	3.1	3.1	2.7	3.3

Source: Our analysis of Center for Naval Analyses data.

Similarly, in the Red Sea, the conventionally powered carriers operating also received aviation fuel every 2 to 3 days. The Center for Naval Analyses stated that, "In practice, ships are topped-off whenever other operational demands make it possible." It reported that from February 17-27, 1991, the peak period of the air campaign, aircraft from the Roosevelt consumed an average of over 4,930 barrels (207,060 gallons) of fuel daily, while U.S.S. America (CV-66) aircraft consumed about 4,990 barrels (209,580 gallons) daily. The amount of aviation fuel consumed daily represented only a small percentage of each carrier's JP-5 capacity.

Ordnance Was Also Replenished Frequently

According to Center for Naval Analyses, ordnance expenditures by the Persian Gulf carriers averaged about 49 tons per day per carrier during the entire war. This rate increased to 116 tons per day during the 4-day ground offensive. Each Red Sea carrier averaged about 43 tons per day during the war and 59 tons per day during the ground war. The smaller Red Sea expenditure rates were probably due to the smaller number of sorties flown as a result of the longer distances these aircraft had to fly to reach their targets. Like fuel, ordnance was also replenished about every 3 days for the Persian Gulf carriers and about every 1 to 2 days in the Red Sea, even though the ordnance expended over a 2- to 3-day period was only a fraction of the ships' storage capacities. For example, according to Center for Naval Analyses, the U.S.S. Theodore Roosevelt (CVN-71) was rearmed seven times during the last 20 days of February 1991, receiving over

1,600 tons of ordnance. During this period, the Roosevelt expended an average of about 2 percent of the capacity (by weight) per day. The U.S.S. Ranger (CV-61) was also rearmed seven times over this interval, even though only about 5 percent of its ordnance capacity was consumed daily. Similarly, the U.S.S. Midway (CV-41) was rearmed nine times between January 16 and February 16, 1991, even though only about 5 percent of its ordnance capacity was expended daily.

List of Aircraft Carrier Hull Numbers, Names, and Authorization and Commissioning and Decommissioning Dates

		Fiscal year ^a		
		Authorized	Commissioned	Decommissioned
Conventionally powered carriers				
CV-59	U.S.S. <u>Forrestal</u>	1952	1955	1993
CV-60	U.S.S. <u>Saratoga</u>	1953	1956	1994
CV-61	U.S.S. <u>Ranger</u>	1954	1957	1993
CV-62	U.S.S. <u>Independence</u>	1955	1959	1998
CV-63	U.S.S. <u>Kitty Hawk</u>	1956	1961	2008
CV-64	U.S.S. <u>Constellation</u>	1957	1962	2003
CV-66	U.S.S. <u>America</u>	1961	1965	1996
CV-67	U.S.S. <u>John F. Kennedy</u>	1963	1968	2018
Nuclear-powered carriers				
CVN-65	U.S.S. <u>Enterprise</u>	1958	1962	2013
CVN-68	U.S.S. <u>Nimitz</u>	1967	1975	2023
CVN-69	U.S.S. <u>Dwight D. Eisenhower</u>	1970	1978	
CVN-70	U.S.S. <u>Carl Vinson</u>	1974	1982	
CVN-71	U.S.S. <u>Theodore Roosevelt</u>	1980	1987	
CVN-72	U.S.S. <u>Abraham Lincoln</u>	1983	1990	
CVN-73	U.S.S. <u>George Washington</u>	1983	1992	
CVN-74	U.S.S. <u>John C. Stennis</u>	1988	1996	
CVN-75	U.S.S. <u>Harry S. Truman</u>	1988	1998	
CVN-76	<u>Ronald Reagan</u> ^b	1995	2003	
CVN-77	Unnamed	2001	2008	
CVX-78	Unnamed	2006	2013	
CVX-79	Unnamed	2011	2018	

^aFuture years are planning dates subject to nuclear fuel state, material condition of the ship, and shipyard building schedules.

^bUnder construction.

Comments From the Department of Defense

Note: GAO comments supplementing those in the report text appear at the end of this appendix.



ACQUISITION AND
TECHNOLOGY

OFFICE OF THE UNDER SECRETARY OF DEFENSE

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Mr. Richard Davis
Director, National Security Analysis
National Security and International
Affairs Division
U.S. General Accounting Office
Washington, DC 20548

30 MAR 1998

Dear Mr. Davis:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "NAVY AIRCRAFT CARRIERS: Cost-Effectiveness of Conventionally and Nuclear Powered Carriers," dated January 28, 1998 (GAO Code 701030/OSD Case 1529). The Department partially concurs with the report.

The Department concurs that there is a life-cycle cost premium associated with nuclear propulsion on aircraft carriers. However, the cost estimate provided by the Navy to the GAO and our preliminary review of the GAO report for both types of carriers indicate that the draft report overstates the premium by several billion dollars, largely because of a number of internal analytic inconsistencies. Further, the Department believes the draft report does not adequately address operational effectiveness features provided by nuclear power.

Currently, the Department is conducting a forward looking analysis of carrier capability and cost in the Analysis of Alternatives for the planned new design carrier CV(X). At the completion of this process, the Department will have detailed life cycle cost estimates for future nuclear and fossil-fueled carrier designs.

The Department does not concur with the GAO's approach of making cost-per-ton comparisons between large, modern, nuclear-powered NIMITZ Class carriers, such as the RONALD REAGAN (CVN-76), and smaller, older, conventionally powered carriers, such as the USS JOHN F. KENNEDY (CV-67). Although the KENNEDY is a very capable ship, its performance reflects the design specifications and processes, fabrication methods, and materials available forty years ago. The difference between KENNEDY and REAGAN is more than simply tons displaced: survivability, habitability, and warfighting capabilities have all been enhanced on the latter-day NIMITZ platforms. The Department believes a more appropriate cost comparison would include pricing conventional and nuclear platforms of equivalent capabilities. Indeed, the Department is comparing such platforms in the aforementioned Analysis of Alternatives.



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Important considerations in any analysis of platform (and propulsion) effectiveness include the mission, threat, and capabilities desired over the anticipated lives of the ship and its class. The GAO report fails to address future requirements in its analysis, instead relying on its analysis of historical data to extrapolate anticipated acceptability. In many cases, this historical analysis fails to account for platform characteristics unrelated to propulsion type. Many of the differences may be more adequately explained by platform size, age, and onboard systems than by how propulsion energy is generated.

Detailed responses to the GAO issues are enclosed, including cost data previously provided to the GAO by the Navy.

The Department appreciates the opportunity to comment on the draft report.

Sincerely,



George R. Schneiter
Director
Strategic and Tactical Systems

Enclosure

Now on pp. 22-23.

See comment 1.

Issue 1: Current conventional and nuclear-powered aircraft carriers share many common attributes. GAO states that "except for their power plants, the conventionally and nuclear-powered aircraft carriers operating in the fleet are very similar in size, form, and function and embark the same standard air wing." GAO uses Table 1.1 to illustrate these similarities between USS JOHN F. KENNEDY (CV 67) and USS NIMITZ (CVN 68). (pp.12-13/GAO Draft Report)

DoD Response: Partially Concur. While DoD agrees that the two ship classes are similar, there are significant differences in their characteristics and employment. First, as GAO notes, KENNEDY is nearly 20,000 tons lighter than the latest NIMITZ class ship and 40-50 feet shorter. Additionally, newer NIMITZ class ships have been upgraded over the last 30 years with improved features, such as electronics, enhanced survivability features, and catapults, while CV 67 has not. As listed in the Handbook for Aircraft Carrier Programs, KENNEDY has over 10 percent less maximum aircraft parking weight, has a smaller hangar deck, can accommodate 15 percent fewer personnel, carries almost 50 percent less JP-5 (aviation fuel), holds less aviation ordnance, and has less endurance. Providing a fossil-fueled carrier with capabilities similar to a NIMITZ Class carrier (except propulsion) would result in a ship about a third larger than KENNEDY, more costly than KENNEDY, and approximately 7000 metric tons larger than the nuclear-powered design.

As can be seen from the above discussion, comparisons of nuclear and nonnuclear carriers using KENNEDY and NIMITZ can be misleading, because the differences between these two ships reflect not only inherent differences in propulsion, but also other differences in designs. Additionally, KENNEDY is not the fossil-fueled carrier that DoD would build today. The additional aviation fuel, ordnance, and survivability features of the latest carrier design would be evaluated for any new fossil-fueled carrier design. Nuclear and nonnuclear designs being considered for CVX include alternatives that have the same size flight deck; the same maximum speed; and the same aviation fuel, ordnance, and survivability features. Furthermore, CVX studies are considering various ship design features to permit examining potential trade-offs in effectiveness and cost. For example, improved propulsion designs may reduce concerns regarding acceleration and rapid maneuvering of fossil-fueled carriers. New nuclear designs also may benefit from design improvements and may achieve lower procurement and life cycle costs than assumed in the GAO report.

In addition to comparing platforms with significant differences other than propulsion type, the GAO's analysis contains other deficiencies. In several instances, GAO provides no analytical basis for their conclusions and does not include some information

See comment 2.

provided by the Navy (recent carrier transits) in their analysis. Additionally, while GAO discusses similar attributes for the two carrier types, GAO does not appear to have evaluated some measures of effectiveness which could show differences between the two propulsion types. These could include actual time on station, vulnerability of logistics, aircraft safety and maintenance, ship readiness and material condition, and tactical flexibility.

Issue 2: Aircraft carriers operate as part of battle groups.

GAO states that "To provide a balanced force to deal with a range of threats, the Navy employs aircraft carriers as part of a combat formation of ships--a carrier battle group--of which it considers the aircraft carrier to be the focal point." GAO notes that the Navy's "Policy for Carrier Battle Groups" (OPNAV Instruction 3501.316 dated February 17, 1995) establishes a "standard carrier battle group" which consists of one nuclear or conventionally-powered aircraft carrier, one carrier air wing, six surface combatants, two attack submarines, and one multipurpose fast combat support ship, "which has the speed and armament to keep up with the other ships. When an AOE is not available, a combination of ships can be used to carry out its role. These include oilers (AO or T-AO) and ammunition ships (AE and T-AE). However, these other types of ships do not carry the range of products that an AOE carries and, since their top speeds are about 20 knots, they do not have the speed to keep up with the other ships in the battle group at all times." GAO notes that this Navy instruction "states that a battle group's composition can vary, depending on the mission needs." (pp. 14-16/GAO Draft Report)

Now on pp. 24-26.

See comment 3.

DoD Response: Do not concur. Throughout the report, GAO assumes that carriers operate exclusively within battle groups. While standard Navy policy notes that aircraft carriers operate within battle groups, this policy does not require carriers to operate exclusively within battle group formations. This policy has been developed for general planning purposes only, vice for use as an operational directive. For the operational situations and force levels that Naval forces are currently facing, carrier employments do not routinely match this planning document. Instead, carrier battle group structure is tailored to meet the war-fighting CINC's needs. For example, the battle group operational commander dictates the speed of advance of the battle group, whether all units are operating together, or if individual units of the battle group, such as the carrier, are tasked to independent operations.

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See comment 4.

CVNs are more frequently tasked to operate independent of the battle group because they are not dependent on propulsion fuel oil. For example, in March 1996, the NIMITZ battle group was ordered to move from the Persian Gulf to the western Pacific. The increased self-sustaining capability of the CVN allowed NIMITZ to remain on-station in the Persian Gulf with only one of its (fossil-fueled) escorts, while the remaining ships in the battle group began the transit toward east Asian waters. Five days later, NIMITZ departed the Gulf and, while en route, refueled her remaining escort and conducted proficiency flight operations prior to overtaking the rest of her battle group as they entered the Taiwan Straits. Nuclear power provided NIMITZ the capability to sustain continued presence in the Gulf, while still meeting the arrival timeline in the Taiwan Straits.

See comment 5.

Fossil-fueled carriers are more dependent on battle group logistics support than a nuclear-powered carrier. Due to fuel consumption concerns during long transits, fossil-fueled carriers can be limited in transits to the slower speeds of their logistics ships. Higher transit speeds can be maintained by CVs, but they require increased prepositioned oilers, complicating logistics support.

See comment 3.

Navy officials informed GAO that carriers frequently operate with limited numbers of escorts, depending on the perceived threat and other fleet needs. Therefore, GAO analyses should not rely completely on historical battle group employment and should consider more recent operations. In the draft report, GAO does not quantify the number of independent or limited escort surge operations performed during recent carrier employments. For example, Appendix IV of the GAO draft report does not discuss any of the carrier surge operations that have occurred in the last several years.

See comment 6.

Issue 3: The aircraft carrier's employment cycle. GAO states that a carrier's employment cycle consists of a depot-level maintenance period, interdeployment training (including air wing deployment), overseas deployment, and a stand-down period following deployment. GAO states that, "The length of a carrier's employment cycle, sometimes called its maintenance cycle, depends on the carrier's propulsion type and the maintenance strategy it uses. For both carrier types, an 18-month operating interval, including the 6-month deployment, separates the maintenance periods." (p. 16/GAO Draft Report)

Now on pp. 26-28.

See comment 7.

DoD Response: Partially Concur. DoD agrees that the carrier's employment cycle generally consists of the four elements described by the GAO. However, DoD does not agree that the length of this cycle depends on propulsion type. Current Navy

guidance, which dictates notional maintenance plans for in-service carriers, has different maintenance plans based on ship class vice propulsion type. For example, the KITTY HAWK class and KENNEDY carriers follow an Engineered Operating Cycle (EOC) that consists of complex overhauls and selected restricted availabilities. Alternately, the maintenance plan for the NIMITZ class carriers was revised in 1994 to an Incremental Maintenance Plan (IMP). This notional maintenance plan consists of Planned Incremental Availabilities (PIAs) and Docking Planned Incremental Availabilities (DPIAs). CNO letter, Ser N43/7U593244, dated September 5, 1997, noted that, "With only a small number of operational CVs remaining, each of which has less than one half its service life remaining, the Navy has not undertaken an updated evaluation to revise maintenance strategies for these CVs." Current notional plans call for slightly less depot maintenance time for the current class of fossil-fueled carriers than for NIMITZ carriers (4 months less over 3 deployment cycles). Current KITTY HAWK and KENNEDY class carrier SRAs are three months in duration vice the six-month PIAs of the nuclear carrier. However, the fossil-fueled carrier class has a 12-month carrier overhaul at the completion of the third deployment cycle; whereas the nuclear carrier has a ten-month DPIA. This disparity in lengths exists due to Navy's aforementioned choice not to evaluate the optimum length of time for the current fossil-fueled carrier's maintenance cycle.

See comment 8.

As stated earlier, NIMITZ class carriers possess many different ship characteristics other than propulsion type, when compared to KITTY HAWK class or KENNEDY fossil-fueled carriers. Therefore, these notional maintenance plans do not isolate maintenance availability differences due only to propulsion type. Additionally, GAO provides no information to indicate that nuclear plant maintenance controls these maintenance schedules. CNO letter, Ser N43/7U593244, dated September 5, 1997, notes that "Should a new class of CVs be developed in the course of studying alternatives for CVX, a new maintenance strategy would also need to be developed, similar in scope and intent to the CVN IMP maintenance plan." A copy of this letter was provided to GAO for use during their analysis.

Issue 4: Nuclear propulsion for aircraft carriers and surface combatants has been the subject of much debate. GAO notes that evaluation of the operational advantages and costs of nuclear-powered surface ships (including carriers) has been the subject of much debate since the 1960s. GAO states that nuclear power advocates within DoD and the Navy have cited larger storage capacity, greater high-speed endurance, and superior acceleration as advantages of nuclear power. GAO cites several quotes by ADM Arleigh Burke from 1960 and 1961 which concluded, at the time,

Now on pp. 34-36.

See comment 9.

that the advantages of nuclear power do not offset the increased cost. In Appendix II, GAO summarizes the advantages of nuclear power and ends the history of this on-going debate in 1963 with the decision to build KENNEDY as a conventionally-powered carrier. (p. 21-23/GAO Draft Report)

DoD Response: Partially Concur. While implementation of nuclear power in surface combatants and aircraft carriers has been the subject of much debate, the GAO characterization of this debate is over 30 years old. Nearly all quotes cited by GAO were prior to initial operations of the first nuclear-powered aircraft carrier, ENTERPRISE, and were made at the time it was decided that KENNEDY would be powered by fossil fuel. GAO does not discuss or summarize the arguments for nuclear power which culminated in Secretary of Defense approval of nuclear propulsion for the 10-ship NIMITZ class.

Issue 5: High costs led the Navy to stop building nuclear-powered surface combatants. GAO notes that during the 1960s and 70s, the Navy pursued a goal of creating a fleet of all-nuclear carrier task forces. However, GAO states, "The Navy ceased building nuclear-powered surface combatants after 1975 because of the high cost. More recently, most of the remaining nuclear-powered surface combatants have been decommissioned early because they were not cost-effective to operate and maintain." Additionally, GAO states "Nuclear-powered surface combatants share many of the characteristics of the nuclear-powered carrier-unlimited high speed endurance, sustainability, and their larger size than their sister ships." (pp. 23-24/GAO Draft Report)

Now on pp. 36-38.

See comment 10.

DoD Response: Partially Concur. Acquisition and life cycle costs of nuclear-powered cruisers were not the sole factor in the decision to inactivate these ships. DoD's rationale for choosing conventional power for Aegis cruisers was due to the risk and cost associated with development of the new Aegis capability in parallel with the new design nuclear propulsion plant that would have been required for this ship. DoD's rationale for deciding to retire nuclear cruisers from continued service is complex and tied to progressive changes in force structure goals, operational and battle group deployment doctrine changes attendant to the end of the Cold war, and decisions not to invest in modernizing obsolete weapons systems.

These same considerations do not directly apply to nuclear power for aircraft carriers. While nuclear power provides both carriers and surface combatants with increased sustainability for a ship of the same size, rapid acceleration, relative independence from the propulsion-fuel logistics train, and high-speed sprint capability, these attributes provide unique

See comment 11.

advantages for carrier operations. Discussion of these advantages for carrier operations is included elsewhere in this response. The size of the nuclear propulsion plant required for an aircraft carrier as a percentage of total ship size is a significantly smaller percentage for nuclear-powered aircraft carriers than for nuclear-powered surface ships, providing additional volume for other uses. Also, due to the smaller overall ship acquisition and life cycle costs for surface combatants than for carriers, the cost premium for nuclear power in aircraft carriers is smaller than that for nuclear-powered surface ships.

Now on p. 39.

Issue 6: GAO operational analysis represents a historical perspective. GAO notes that their operational effectiveness analysis "represents a historical perspective--the experiences of the Navy over the past several years operating a mixed force of conventionally-powered and nuclear-powered ships. That perspective addresses a broad spectrum of operations that includes providing routine peacetime presence, the Navy's response to emerging crises such as the movement of Iraqi forces to the Kuwait border in 1994, and the open conflict of Operation Desert Storm." (p. 26/GAO Draft Report)

See comment 12.

DoD Response: Partially Concur. For most of the analysis, GAO estimated the operational benefits and costs associated with current NIMITZ Class and KITTY HAWK and KENNEDY Class carriers over the last 30+ years. Drawing valid conclusions on propulsion type from these data is very difficult. The current nuclear-powered and fossil-fueled carriers in the fleet represent a myriad of operational capabilities and acquisition, maintenance, and operational costs.

A forward looking approach comparing new designs for both nuclear-powered and fossil-fueled carriers would be more relevant to the future DoD decision on the features of the next generation carrier. To isolate inherent propulsion plant differences, this approach would include consideration of alternatives that maintain all capabilities, other than those inherent to propulsion, constant between nuclear and fossil-fueled designs. Doing this would result in fossil-fueled carriers of larger size, with equivalent aviation ordnance and fuel capacities, as well as the same passive protection features, as CVNs.

Additionally, the approach would include alternatives that incorporate new design technologies, construction methods, and operational requirements that have been developed for both fossil-fueled and nuclear propulsion plants over the last 30 years. For example, technologies that enabled significant reductions in the number of pumps, valves, and total parts for

the New Attack Submarine propulsion plant design as compared to the NIMITZ vintage LOS ANGELES Class (SSN 688) propulsion plant designs should be considered for a new design CVN. Similarly, possible gas turbine technology or upgraded oil-fired steam propulsion plants should be considered for the CV. This forward-looking approach is consistent with that being used by DoD to base decisions on the design of the next generation aircraft carrier, CVX.

The GAO draft study compares the costs (escalated) of a 30-year-old CV 67 with current NIMITZ Class ship costs. Yet, some portions of the operational effectiveness assessment assume a new-design CV of NIMITZ-comparable characteristics and war-fighting performance (without the associated development and acquisition cost for these capabilities).

Issue 7: Both types of carriers have been effective in fulfilling forward presence requirements and the Navy employs them interchangeably. Both carrier types satisfy theater commanders' needs. GAO states "Our analysis indicates that conventionally-powered and nuclear-powered carriers both have been effective in meeting national security objectives and requirements, share many characteristics and capabilities, and that the Navy employs them interchangeably." Additionally, GAO notes that "Joint Staff and combatant command officials told us that the quality of presence provided by both types of carriers is indistinguishable....Joint staff and officials at two unified commands said that a carrier's type of propulsion is not a critical factor in making employment decisions." (pp. 26-28/GAO Draft Report)

DoD Response: Partially Concur. The Department agrees that both nuclear-powered and fossil-fueled carriers have been effective in fulfilling forward presence requirements. However, contrary to GAO statements, the carrier's type of propulsion is a factor in making employment decisions. Although the GAO acknowledges advantages for nuclear-powered carriers, they do not adequately address the magnitude of support required by the fossil-fueled carrier which requires deliberate planning. According to COMLOGGRU TWO, a nuclear carrier would require at most one underway replenishment of aviation fuel during a 9- to 10-day transit (depending on the level of flight operations). However, the fossil-fueled carrier would have emptied the oiler of useable fuel by the time it reached its destination, requiring an additional oiler to replenish the CV before it would be able to engage in war-fighting.

Also, in numerous places throughout the report, GAO asserts that operational guidance and Navy planning do not distinguish between

fossil-fueled and nuclear-powered carriers. Aircraft carrier force levels do not permit differentiation between type. Because of limited numbers, operational commanders task the closest or next-to-deploy carrier instead of selecting any particular carrier. Therefore, Navy planners ensure proper disposition of required logistics support to make differences in operational capability due to propulsion as transparent as possible to the war-fighting CINC.

The attached comments from CENTCOM, PACOM, and the Navy (CINCPACFLT, COMUSNAVCENT, CINCUSNAVEUR and CINCLANTFLT) note operational benefits provided by nuclear power.

Issue 8: Conventional carriers are more available due to their less-demanding maintenance requirements. GAO states that due to decreased maintenance requirements, conventional carriers "are more available for deployment and other fleet operations." GAO based this conclusion on analysis of the Navy's notional carrier maintenance requirements (contained in OPNAVNOTE 4700) and actual maintenance data for the period October 1984 through December 1996. Using the notional maintenance schedules provided by OPNAVNOTE 4700, CVs spend approximately 5 percent less time in maintenance than nuclear-powered carriers. GAO also "compared the proportion of time the two carrier types spent in depot-level maintenance from October 1984 through December 1996 and found that, collectively, the ships of each type spent about 30 percent of their time undergoing depot-level maintenance. However, during that time, three conventional carriers underwent a Service Life Extension Program (SLEP) while, because of their relatively short times in service, none of the NIMITZ-class nuclear carriers were refueled. When we adjusted the data to reflect the time they would typically have spent in an overhaul, the conventional carriers would have collectively spent 23 percent of their time in depot-level maintenance, about 7 percent less time than did the nuclear carriers with complex overhauls." GAO noted that "The difference [in actual maintenance availability] between the two carrier types is generally consistent with their notional (planned) maintenance cycles."

Based on this analysis of maintenance requirements, GAO concludes that, "Because less depot-level maintenance is needed, conventionally powered carriers would be available for fleet operations about 5 percent more time than nuclear carriers during a single maintenance cycle. As table 2.1 shows, this is consistent with the adjusted data for the October 1984 through December 1996 period." (pp. 28-30/GAO Draft Report)

DoD Response: Do not concur. Actual maintenance data provided to GAO shows that, on average, Nimitz class CVNs were

Now on pp. 41-44.

See comment 15.

approximately 5 percent more available than in-service CVs for the time period of October 1, 1983 to September 30, 1996 (Fiscal Years 1984-1996). GAO notes that a number of CVs underwent SLEPs during this time which may have skewed the data. Therefore, GAO adjusted the data to account for this effect. However, GAO's method for performing this adjustment is not explained in the report. Adjusting the data to account for SLEP differences does not support GAO's conclusions that CVs were approximately 7 percent more available than CVNs.

See comment 16.

Other factors also would affect the data. During this time frame, 6 of 9 CVs were inactivated (or within 5 years of inactivation), which affects the data used for this comparison. By law, ships within 5 years of inactivation cannot be modernized without specific approval by the Secretary of the Navy. This results in less modernization being performed on the majority of CVs evaluated. On the other hand, CVs undergoing maintenance in this period were, on average, older than the NIMITZ class CVNs, and thus may have required additional maintenance.

See comment 17.

GAO also did not isolate differences in maintenance times based on propulsion plant differences vice ship class differences. For example, during this time frame, upgrades to carriers that were not propulsion-plant specific (e.g., women-at-sea modifications, new technology/electronics upgrades) were implemented. Additionally, specific maintenance time frames are dependent on particular shipyard availability schedules.

It does not appear GAO adjusted their analysis for the above effects. Therefore, conclusions drawn from these data could be misleading.

See comment 18.

Last, carrier maintenance schedules are driven by operational requirements, not vice versa. As noted by CINCLANTFLT, "carrier maintenance schedules are developed based on deployment schedules. If deployment schedules change, the maintenance schedules can be modified as well."

Issue 9: Conventionally powered carrier force could provide more overseas presence than a like-sized nuclear force. GAO's "analysis of force requirement estimates for overseas presence, derived from the Navy's Force Presence Model, shows an all-conventional carrier force could either provide a greater level of overseas presence or require fewer carriers to meet U.S. peacetime presence requirements than would an all-nuclear carrier force." GAO notes that the Global Naval Force Presence Policy (GNFPP) "does not differentiate between conventional and nuclear carriers." However, "Several variables enter into the equation that calculates the carrier force level required to attain a

Now on pp. 44-48.

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level of peacetime presence. These variables include the time spent in depot-level maintenance, the restrictions imposed by the PERSTEMPO policy, the distance carriers must transit from their U.S. home ports to the overseas theater, the speed of the transit, and the length of deployment." Tables 2.2 and 2.3 provide the results of the GAO's calculation of presence coverage for the two types of carriers. (pp. 31-35/GAO Draft Report)

DoD Response: Do not concur. GAO makes use of incorrect assumptions regarding differences in maintenance cycles for fossil-fueled and nuclear-powered carriers (Issues 3 and 8). Since the maintenance plans for any new-design CV/CVNs would be similar (CNO letter, SER 43/7U593244, dated September 9, 1997, addresses this point), proper use of the Force Presence Model would yield results showing essentially no difference in forward presence provided by the two types of carriers. Other considerations, including scheduling uncertainties and unplanned contingencies, also should be considered when establishing force levels. DoD concluded that a force of 12 carriers is necessary to satisfy current policy for forward-deployed carriers and accommodate real world scheduling constraints.

Issue 10: For response to crises or Major Theater War, Nuclear-powered carrier's unlimited high speed range reduces transit times by a few hours. GAO notes that "Because nuclear-powered carriers do not need to slow for underway replenishment of propulsion fuel, they can transit long distances faster than can conventional carriers. Even though both types have similar top speeds, a conventional carrier normally slows to a speed of about 14 knots during underway replenishment. Our analysis showed that a conventional carrier, steaming at 28 knots, would arrive 4 or 5 hours later than a nuclear carrier on a 12,000-nautical mile voyage (the distance from San Diego, California, to the Persian Gulf) and would have been refueled 3 times. On a 4,800-nautical mile voyage (the distance from Norfolk, Virginia, to the eastern Mediterranean Sea), the conventional carrier, steaming at 28 knots, would arrive 2 hours later than a nuclear carrier. As table 2.4 shows, in most cases, a nuclear carrier completes a transit more quickly than does a conventional carrier." As footnote b to this table, GAO notes, "The number of refuelings required is based on refueling the conventional carrier when its propulsion fuel level reaches 30 percent of capacity."

Further, GAO notes that "carriers being escorted by conventionally-powered surface combatants would transit more slowly because of the escorts' need to replenish more frequently. As a result, the overall transit speeds of both types of carrier battle groups would be slower than those shown, if all of the ships in the battle group were to arrive in the same vicinity at

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about the same time. A comparison of transit times of nuclear and conventional carriers that have responded to several crises in this decade is presented in appendix IV." (pp. 36-37/GAO Draft Report)

DoD Response: Do not concur. GAO assumes that because CVs and CVNs have similar top-end design speeds, both types of carriers can maintain this speed for sustained periods; the only difference being the fossil-fueled carrier's need to infrequently slow down for a few hours to refuel. In reality, a CV would require increased logistics support to accomplish these transits or would slow to more economical speeds, reducing logistics support, but arriving several days later. The 28-knot transits assumed by GAO understate logistics planning, propulsion plant watch standing and reliability concerns for sustained steaming periods, and increased fuel consumption costs required to maintain this SOA for current fossil-fueled carriers.

A CV and AOE transiting at 28 knots would require:

- Nearly 3-1/2 to 4 million gallons of propulsion fuel for a 4800 nm transit, or nearly 9-10 million gallons of propulsion fuel (the equivalent of 3 additional AOE's propulsion fuel capacity) for a 12,000 nm transit. If transiting within a battle group, this would double the propulsion fuel needs of the carrier battle group.
- Operating all 8 of the CV's boilers for an extended period of time (7-18 days). Propulsion plant operations, as well as maintenance and watch-standing requirements, would be stressed during this transit. Based on historical oil-fired steam maintenance history, a CV would have difficulty routinely completing these transits as assumed.
- Normal replenishment prior to decreasing below 50-60 percent of fuel capacity, rather than the 30 percent assumed by GAO. This fleet commander requirement accounts for uncertainties in weather conditions, logistic force availability, and operational needs.

Alternately, CVs could transit at more economical speeds, reducing fuel-oil consumption and propulsion-fuel logistics support, but arriving several days later for a 4800 nm transit or over a week later for a 12,000 nm transit.

Therefore, CVNs routinely transit at speeds greater than CVs. While geographic choke points, sea states, and operational evolutions (underway replenishment, flight operations) may decrease speed of advance, the CVN's ability to proceed at

See comment 25.

maximum speed during the other portion of a transit provide for an overall higher speed of advance than for a fossil-fueled carrier.

The Navy provided GAO with information from several CVN transits over the last several years. GAO did not include this information in their draft report.

Issue 11: For response to crises or Major Theater War, a conventionally-powered carrier can more easily surge from maintenance. GAO states that "Navy officials said that it's easier to shorten the conventional carriers' maintenance periods than it is for those of the nuclear carriers and that this is an important factor governing the carriers' ability to respond to a major crisis." GAO further states that "Navy officials said, and documents show, that due to the complexity of its maintenance, a nuclear carrier's maintenance period cannot be shortened to the same degree as that of a conventional carrier." GAO generated Figures 2.3 and 2.4 to illustrate the differing abilities to surge from maintenance. (pp. 38-40/GAO Draft Report)

Now on pp. 51-54.

See comment 26.

DoD Response: Do not concur. The ability of any carrier to surge from maintenance is dictated by the scope and complexity of the maintenance to be performed, which varies from availability to availability. GAO provides no factual or analytical basis for the above conclusion or to validate the information in the report.

Issue 12: Conventionally-and nuclear-powered carriers were both effective in the Persian Gulf War, a war that portends the types of conflict in which U. S. Forces expect to be engaged in the foreseeable future. (p. 41-44/GAO Draft Report)

Now on pp. 55-61.

See comment 27.

DoD Response: Do not concur. The discussion of wartime utilization focuses solely on Desert Shield/Desert Storm as the definitive wartime scenario, where we had the luxury of a large supply of oil nearby, little opposition to our ships except for mines, and sufficient pre-planning time. Current DoD planning scenarios envision a much more stressing threat and do not assume the favorable logistics conditions present in Desert Storm.

Issue 13: Nuclear and conventional carriers employ a standard air wing and, therefore, do not differ in sortie generation capability. GAO notes that the standard composition for the air wing is the same for both conventionally and nuclear-powered aircraft carriers. Therefore, both types of carriers are

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expected to generate the same number of sorties per day. (p. 45-47/GAO Draft Report)

DoD Response: Partially concur. Propulsion plant type can affect sortie generation capability in light wind conditions or when downwind air operations are necessary. Carriers are required to maintain a minimum amount of wind across their decks for flight operations. In the absence of naturally occurring wind, carriers must generate their own by using the ship's forward movement. CVNs can do this quickly and sustain these speeds indefinitely without adversely impacting the crew or consuming large amounts of fuel oil. For current oil-fired steam carriers to maintain high sustained speed to generate its own wind requires significant effort in the propulsion plant. More boilers are required on-line for an extended period of time with attendant increases in fuel consumption, watch standing, and maintenance requirements. Potential new design fossil-fueled carriers might have different propulsion plants (e.g., gas turbines) that may mitigate some of these limitations.

Finding 14: Propulsion Type Does Not Materially Affect Survivability. GAO states that "Officials of the Naval Sea Systems Command told us, according to their survivability analyses, neither type of carrier possesses any inherent, overriding advantage over the other in its susceptibility to detection or its vulnerability to the damage inflicted by the weapons." Additionally, GAO notes that "Naval Sea Systems Command officials believe that the nuclear carrier's speed and unlimited range give it a distinct operational advantage, but they also told us that there were no analytical studies addressing these operational factors to support this belief."

GAO also noted Navy officials' statements that, since nuclear carriers do not have to replenish propulsion fuel and can replenish aviation fuel and ordnance less frequently, they have fewer refuelings, a vulnerable time for any ship. However, GAO notes that "Since carriers normally replenish all supplies and fuel during an underway replenishment, a conventional carrier normally takes on DFM [diesel fuel, marine] and JP-5 simultaneously" and, therefore, would be no more vulnerable due to propulsion fuel needs. Finally, a carrier refueling "takes place under the defensive umbrella of the surface combatants of the battle group." (pp. 48-49/GAO Draft Report)

Now on pp. 65-66.

See comment 29.

DoD Response: Do not concur. The discussion on this topic misrepresents the Navy's position. Contrary to GAO statements, NAVSEA letter, Ser PMS 312G/C03, dated January 29, 1997, indicates significant differences in survivability between current fossil-fueled and NIMITZ class carriers. Specifically,

this letter noted that "the nuclear propulsion system of the CVNs gives it an edge in all three categories [susceptibility to detection, vulnerability to damage/destruction, and ability to regain operating capability]." Additionally, CVNs are less susceptible to damage from fire in the propulsion spaces due to minimum fuel oil piping within the propulsion plant spaces. The Navy also noted that "the larger aviation fuel and ordnance and increased propulsion endurance inherent in a nuclear-powered carrier result in fundamental detectability and vulnerability differences between the CV and CVN. The smaller storage capacities [of current conventional carriers] result in more frequent refuelings--a slow vulnerable time for the carrier."

Since current CVNs have larger aviation fuel and ordnance capacities and no need for boiler fuel, the CVN battle group commander has both greater tactical flexibility and increased attack effectiveness. Without the worry of propulsion fuel reserves, a CVN can transit long distances at maximum speed, avoid adverse weather conditions, and use evasive transit tracks to launch and recover aircraft. Incorporating these features in a CV would increase its size.

Later NIMITZ class carriers have increased survivability features. While these features are unrelated to the propulsion plant, they are present in current day NIMITZ class carriers, which GAO used in their cost analysis. Incorporation of these features in a fossil-fueled carrier would increase its displacement and cost relative to current fossil-fueled carriers.

Issue 15: The larger storage capacity of nuclear carriers is due primarily to ship design. GAO states that "The larger fuel and ordnance storage capacities of the nuclear carrier are primarily due to ship design differences that have little to do with the type of propulsion and the fact that nuclear carriers do not have to store large amounts of propulsion fuel Additionally, a 1992 Center for Naval Analyses research memorandum documenting the feasibility of five alternative aircraft carrier concepts developed by Naval Sea Systems Command stated that, other than endurance range, a carrier built with a NIMITZ-type hull powered by a KENNEDY-type oil-fired steam plant would be essentially equivalent to the NIMITZ-class design." (pp. 50-52/GAO Draft Report)

DoD Response: Partially concur. Due to propulsion plant power and energy density differences, more storage capacity would be available in a nuclear-powered ship than a fossil-fueled ship of the same size. A fossil-fueled carrier could be provided with combat consumable capacities comparable to a NIMITZ class CVN.

Now on pp. 67-68

See comment 30.

However, this new design CV would be a significantly larger, heavier-displacement ship.

Issue 16: At sea replenishment offsets the conventional carrier's more limited storage capacity and endurance.

GAO states that due to the need for CVNs to replenish aviation fuel and ordnance, as well as their conventional escorts' need to replenish propulsion fuel, nuclear carrier battle groups do not have infinite sustainability. The presence of an AOE within the battle group provides both nuclear carrier and conventional carrier battle groups with increased sustainability. GAO notes, "Station ships, such as the AOE multipurpose fast combat support ship, are an integral element of carrier battle groups, routinely resupplying the other ships in the group. AOE's can simultaneously deliver fuel, ordnance, and other supplies." Further, "According to Navy logistics doctrine, station ships support a typical battle group with fuel for 20-30 days, consumables (other than fuel and ordnance) for 75 days, and spare parts for 90 days."

Appendix III provides details about the current Navy logistics force and compares the range and endurance of carrier battle groups. GAO also concludes that the capabilities of the nuclear-powered and conventionally-powered battle group with an AOE in the battle group are about the same. (pp.51, 104-105/GAO Draft Report)

DoD Response: Partially concur. As noted in responses to previous issues, increases to the planned logistics force would be required to support an all-CV fleet capable of meeting presence requirements and crisis response. At-sea replenishment forces can increase the carrier's sustainability, and somewhat offset the fossil-fueled carrier's more-limited storage capacity. However, reliance on logistics forces to maintain needed consumable capacities means that a fossil-fueled carrier is more tied to logistics support and would be more affected by the vulnerability of its logistic support than would a nuclear-powered carrier.

Issue 17: Nuclear carriers have greater acceleration capability.

GAO notes that a CVN has a greater acceleration capability and that "Navy officials said that a nuclear carrier would be better able to recover landing aircraft if wind and weather conditions suddenly changed, or if the aircraft experienced mechanical difficulties, since it could accelerate more quickly than a fossil-fueled carrier to generate the additional 'wind over deck' needed to safely land an aircraft." However, GAO's review of Navy safety center data for aircraft indicates that flight deck

Now on pp. 68-69
and 127-133.

See comment 31.

Now on pp. 70-71.

See comment 32.

layout and other design features rather than the type of ship propulsion play a greater role in aircraft safety. Additionally, "Navy officials could not provide us examples of aircraft being lost because a conventional carrier could not accelerate fast enough. Additionally, a Naval Safety Center official told us that the center had no record of an aircraft crashing because a carrier could not increase its speed quickly enough." (pp. 52-53/GAO Draft Report)

DoD Response: Partially Concur. Aircraft attrition is not the only indicator of the advantages of greater acceleration capabilities. The lesser acceleration of fossil-fueled carriers has resulted in the inability to rapidly increase wind over the deck that causes: aircraft to delay recovery (wave-off), extended recovery cycles, aircraft to divert to non-mission supporting airfields, compressed aircraft turn-around times/rushed maintenance personnel resulting in the inability to make subsequent launches.

Additionally, greater acceleration capability increases ship survivability by decreasing a potential enemy's tactical ability to target the carrier and improves the carrier's ability to operate in constrained operating spaces. Rapid acceleration and high-speed capabilities allow the CVN to evade potential threats, such as small boats and submarines. As noted previously, potential new design fossil-fueled carriers may have power plants that could mitigate some of the limitations of current fossil-fueled carriers.

Issue 18: Home porting a nuclear-powered carrier in Japan could be difficult. GAO states that "Home porting a nuclear-powered carrier permanently at Yokosuka would require a major base reorganization, including nuclear-propulsion maintenance and support facilities, upgraded utilities, and dredging of the harbor and approach to accommodate a deeper draft ship. It would also require additional family housing and support facilities. Although funds could be obtained through the Japanese Facilities Improvement program, the approval process could be lengthy. GAO uses information contained in the Navy's March 1995 report entitled NIMITZ-Class Aircraft Carrier Home porting Cost Comparison Between NAS (Naval Air Station) North Island and NSY (Naval Shipyard) Long Beach" to support this conclusion. (pp. 77-82/GAO Draft Report)

Now on pp. 98-103.

DoD Response: Partially Concur. Infrastructure changes required if a CVN were home-ported in Japan would not be as significant as stated, because the non-propulsion plant maintenance would continue to be supported by Ship Repair Facility (SRF) Yokosuka. For the propulsion plant, previous CVN maintenance plans have

shown that CVNs can be operated for long periods between depot maintenance availabilities. Although current maintenance plans have demonstrated advantages for the unique case of home porting overseas, the home-ported CVN could modify its maintenance plan as follows:

- Improve ship's force ability to maintain the propulsion plant independent of base support.
- Augment shipboard maintenance with fly-away teams as required.
- Return the home-ported carrier to CONUS for depot-level work on a periodic basis (nominally 6-12 years) and replace her with another carrier to be home-ported in Japan.

This would provide sufficient flexibility so that significant propulsion plant support facilities would not be needed in Japan. This is not unprecedented. SSBNs, which were home-ported overseas in the U.K. and Spain, were maintained by a U.S. submarine tender, but returned to CONUS for depot-level work.

Additionally, GAO attributes several changes to base infrastructure and facilities due to the larger ship and crew size of a NIMITZ class carrier. Home-porting any carrier larger than the current home-ported carrier would require some changes to base support infrastructure regardless of propulsion type. Also, NIMITZ class carriers currently visit Yokosuka for port calls.

ISSUE 19: Life-Cycle Costs for Nuclear-Powered Aircraft Carriers Are Greater Than for Conventionally-Powered Carriers. GAO found that one of the most persistent challenges facing the DoD is the ability to provide adequate resources for the acquisition, operations, and support of its systems and equipment. GAO noted that understanding a weapons systems total life-cycle cost is a keystone to sound acquisition decisions. To develop a life-cycle cost model to estimate costs for nuclear and conventionally-powered aircraft carriers, GAO used a combination of the USS KENNEDY and older smaller USS AMERICA, USS CONSTELLATION and USS KITTY HAWK as the baseline for a conventional carrier and the more modern NIMITZ class for a nuclear carrier.

Based on their analysis, the GAO concluded a nuclear-powered carrier costs about \$9.3 billion more than a conventionally-powered carrier to acquire, operate, and support for 50 years, and then to inactivate. (pp. 54-56/GAO Draft Report)

Now on pp. 73-75.

DoD Response: Partially concur. The Department agrees that a thorough understanding of total life-cycle costs is key to allocating scarce resources within the Department. Just as important, however, is ensuring that life-cycle cost analyses of different alternatives are based on accurate and relevant information. The Department does not agree with the GAO's cost approach of comparing modern NIMITZ Class carriers, such as CVN 76, to smaller, less-capable, older fossil-fueled carriers, such as USS KENNEDY (CV 67).

GAO estimated the cost of another USS KENNEDY (CV 67). Using CV 67 and older CVs as benchmarks does not acknowledge that DoD would not buy a repeat of this 40-year-old design, given today's war-fighting requirements. Additionally, industry would not build a CV 67 today with the same design standards, materials, and specifications. Carrier characteristics have changed greatly since CV 67 was designed (e.g., side armor, electronics, habitability, etc.). The CV 67 design does not meet current standards for survivability, habitability, or capability incorporated in ships built today.

Currently, the Department is conducting a forward-looking analysis of carrier capability and cost in the Analysis of Alternatives (AOA) for the planned new design carrier CV(X). The analysis on propulsion type will be completed this year with a decision scheduled for the end of FY98.

The Department has not established a cost estimate for any particular future CV or CVN design. Estimates prepared by the Navy, however, illustrate the higher costs associated with producing and supporting a fossil-fueled carrier meeting NIMITZ Class standards.

The Navy estimate (which was provided to GAO) represents the costs of a "NIMITZ-like" fossil-fueled carrier, comparable in capability (except for capabilities provided by propulsion type) to a new NIMITZ Class ship (CVN 76) (i.e., comparable in aviation fuel endurance, ordnance loading, survivability features, and electronics).

In the Navy estimate, the 50-year life-cycle costs of a CVN are about \$1.6 billion (~7 percent) more than a fossil-fueled carrier of the same size and capability (except propulsion) vice the \$9.3 billion estimated by the GAO. Furthermore, GAO's CV 67 fossil-fueled carrier estimate is several billion dollars lower than the Navy's estimate.

DoD Response: Partially concur. The Department agrees that a thorough understanding of total life-cycle costs is key to allocating scarce resources within the Department. Just as important, however, is ensuring that life-cycle cost analyses of different alternatives are based on accurate and relevant information. The Department does not agree with the GAO's cost approach of comparing modern NIMITZ Class carriers, such as CVN 76, to smaller, less-capable, older fossil-fueled carriers, such as USS KENNEDY (CV 67).

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Appendix VII
Comments From the Department of Defense

NAVY ESTIMATE OF SINGLE SHIP LIFE CYCLE COST
(for comparison purposes only)

Cost Category (FY 97 dollars in millions)	CV Nimitz Like	CVN 76	CV 67
Investment	\$4,776	\$6,578	\$3,826
Operating and Support	\$16,307	\$15,642	\$15,076
Inactivation/Disposal	\$64	\$525	\$50
TOTAL Life Cycle Cost	\$21,147	\$22,745	\$18,952
Investment	\$4,776	\$6,578	\$3,826
Acquisition	\$3,528	\$4,408	\$2,845
RCOH/SLEP	\$1,248	\$2,170	\$981
Operating and Support	\$16,307	\$15,642	\$15,076
Personnel	\$8,807	\$9,117	\$8,600
Depot Maintenance	\$4,870	\$5,405	\$4,333
Other	\$2,630	\$1,120	\$2,143
Inactivation/Disposal	\$64	\$525	\$50
Inactivation	\$64	\$513	\$50
Spent nuclear fuel storage		\$12	

As noted previously, potential new design nuclear propulsion plants could implement improvements which may mitigate this cost premium.

In addition to the above concerns, the Department identified several specific errors in the GAO analysis unrelated to Class differences.

Fossil Fuel Delivery. The GAO estimate does not include acquisition cost for combat logistics forces (CLF) needed to support an all fossil-fueled CV fleet or replacement cost of oilers. The GAO claims these costs cannot be included because comparable acquisition costs for nuclear facilities (DOE labs) cannot be estimated. The Department does not find this argument compelling: the appropriate recurring elements of both CLF and support (nuclear and nonnuclear) costs should be included.

Training Cost. The GAO estimate of CVN propulsion plant pipeline training costs is overstated by about \$437 million per ship. How the GAO calculated their cost figure is not clear. The Engineering and Reactor Departments on a NIMITZ carrier consists of 749 people but only ~330 of these are nuclear-trained officers and enlisted who go through hands-on training. Given an average personnel rotation of 36 months, approximately 110 nuclear-pipeline-trained personnel would rotate onboard a CVN per year, a

Now on p. 91.
See comment 33.

Now on pp. 89-90.
See comment 34.

portion of whom would not be on their first tour, and, therefore, would have gone through the training pipeline at an earlier date.

The total cost to the Navy of operating, maintaining, and conducting hands-on training, including the salaries of students and Navy staff (for submarine as well as surface personnel), is roughly \$142 million in Fiscal Year 1997 dollars. Approximately 2000 personnel graduate from hands-on training per year. Conservatively assuming 100 students go through prototype training per year to support a CVN (actual number is less than 60 students per year), these students would consume 5 percent or \$7.1 million of the annual hands-on training costs, and an additional \$2 million in student salaries, for a total of \$9.1 million. This is far less than GAO's estimate of \$17.85 million. Adding this to the GAO estimate for CVN initial training gives a total annual training cost of \$13.4 million per ship, and a life-cycle cost of \$669 million per ship. This life-cycle cost is only 60 percent of the GAO estimate of \$1,106 million.

Nuclear Support Activities. The GAO over estimates the nuclear support costs for a single CVN by \$2.4 - \$2.7 billion. GAO's method for allocating nuclear support activity costs to a single ship would require over 82 percent of the total nuclear support cost to support a fleet of 12 CVNs. The amount of uranium burned or shaft horsepower of a large reactor such as NIMITZ class reactors does not proportionally increase their support cost over that of other reactor types as assumed by the GAO. There are several methods that would more accurately allocate these costs to a single CVN.

- One method would be to proportionally spread the costs based on the number of nuclear-powered ships which, over the period measured by the GAO, would result in about 0.8 percent of the nuclear support cost being allocated to a single CVN (1 ship of 130 (average number of nuclear-powered ships for FY91-97)). This would amount to about \$470 million over the 50-year life of a CVN.

- Another potentially valid method, which GAO attempted to use on a portion of the costs, would be to allocate the total nuclear support activity costs over the number of reactor plant types supported (9), and then allocate those costs over the number of ships in that reactor plant type. (The GAO failed to allocate the cost over the number of ships in that plant type.) This method would result in about 1.6 percent of the nuclear support cost being allocated to a single CVN for 7 CVNs (the average number of CVNs over the period examined by GAO) and 0.9 percent for 12 CVNs. This results in nuclear support costs for a single CVN of between \$435 million and \$752 million over a 50-year life.

- A third method would be to allocate costs based on the total number of cores supported during this time period (154). Each NIMITZ class CVN has two cores, so the percent allocated to a single CVN would be 1.3 percent, or \$611 million over a CVN's 50-year life.

The range of costs using these methods is \$435 million to \$752 million--substantially less than the GAO estimate.

Additionally, while the GAO does include nuclear infrastructure and support costs unique to CVNs, it includes no design/support infrastructure costs unique to CV fossil-fueled propulsion plants or the environmental costs of operating an all-fossil-fueled CV fleet.

Carrier Disposal Cost. The GAO's estimate for a nuclear carrier inactivation is overstated by \$400 million per ship. GAO used an out-of-date 1992 rough-order-of-magnitude estimate for inactivating the lead ship (NIMITZ) in FY98. This estimate assumed little advance planning for an efficient inactivation process and did not reflect learning from conducting a series of scheduled NIMITZ class refuelings/defuelings. The Navy's current estimate of \$500 million per ship is based on careful planning for the forthcoming FY98 NIMITZ refueling overhaul (an estimate which has been reduced by over 30 percent since 1992) and on return cost data from nuclear ship defueling/inactivation work.

Spent Nuclear Fuel Storage. The GAO estimate for spent nuclear fuel storage is overestimated by \$144 million per ship. The GAO estimate assumed storage of CVN spent fuel in water pools at the Idaho Chemical Processing Plant despite being informed by The Department of Energy that water storage will not be used for CVN spent fuel. The GAO was provided a DOE estimate of \$12 million per ship for storing 2 shipsets (initial and refueling cores) of NIMITZ class cores in dry storage--75 years for the initial cores and 50 years for the refueling cores.

Now on pp. 93-94.
See comment 36.

Now on pp. 94-96..
See comment 37.

The following are our comments on DOD's letter dated March 30, 1998.

GAO Comments

1. We note that conventionally powered carriers have been upgraded with new features. During their midlife modernization periods, the carriers received extensive rehabilitation and upgrading of their hull, propulsion, auxiliary machinery, electrical and piping systems, improved radars and communications equipment, and aircraft launch and recovery systems. Kevlar armor was added to vital spaces. As part of the Navy's Fleet Modernization Program, the fleet is continuously upgraded with new weapons and electronics systems, as well as other features. For example, one of the conventionally powered carriers, the U.S.S. Constellation (CV-64), has received several upgrades to its aviation maintenance equipment; intelligence, combat, engineering, and navigation systems; and habitability, and it embarks the newest and most capable aircraft that exist in the Navy. At the time of our visit to the U.S.S. Kitty Hawk (CV-63), the commanding officer told us that it had the most modern systems installed in the command, control, communications, computers, and intelligence (C4I) area and that its joint force air component commander (JFACC) is the model for West coast carriers. Another conventionally powered carrier, the U.S.S. John F. Kennedy (CV-67), was the first carrier to operationally deploy with two state-of-the-art intelligence systems, the Battle Group Passive Horizon Extension System and the Common High Bandwidth Data Link. The conventionally powered carriers also are scheduled to receive cooperative engagement capability¹ along with their nuclear-powered counterparts.

We disagree that a new design conventionally powered carrier would necessarily result in a larger and heavier ship. The assumptions underlying this statement disregard the space and weight made available through adopting new technologies and the reduced personnel requirements for the ship and its air wing. Personnel reduction goals for the next carrier ship's force are about 50 percent. Potential air wing reductions can be illustrated by the personnel savings expected in replacing F-14A squadrons with two-seat F/A-18E/F squadrons. An F-14 squadron generally requires 275 maintenance personnel, while an F/A-18E/F squadron will require about 180, a reduction of about 35 percent. For an air wing of 2,480 persons, this could result in a reduction of about 870 persons. Cumulatively, these reductions are expected to require less demand for

¹This capability is a computer-based system that permits simultaneous sharing of detailed targeting data between ships or forces at extensive ranges within the littoral area, thereby increasing reaction time and firing opportunities against enemy missile attacks.

hotel services such as mess halls, berthing, laundry, and food stores and free up space and weight for aviation fuel and ordnance.

2. We believe the measures of effectiveness we chose are appropriate for comparing the two types of carriers. Our methodology for evaluating the effectiveness of conventionally and nuclear-powered carriers uses performance-based mission outcomes (national security objectives) as its metric and is not engineering requirements derived (maximum speed or load carrying capacity). We coordinated our measures of effectiveness with Joint Staff, Office of the Secretary of Defense, and Navy officials. In fact, some senior Navy officials said that they believed that our methodology was sound.

3. We do not state that carriers operate exclusively with battle groups. Rather, we state that a battle group's composition can vary depending on the mission need. For example, figure 1.1 and related text shows a CVN "surging" from the Mediterranean Sea to the Gulf, with elements of its battle group, including a supporting fast combat support ship. The carrier left five of its battle group ships in the Mediterranean Sea, including a nuclear-powered cruiser.

4. Our analysis of the ship deck logs for the U.S.S. Nimitz does not support DOD's statement. According to the logs, ships of the U.S.S. Nimitz battle group passed through the Strait of Hormuz around 6:00 p.m. on March 12, 1996, while the U.S.S. Nimitz exited the Strait of Hormuz around 10:00 a.m. on March 14, 1996, approximately a day and a half later. We note that while the U.S.S. Nimitz and one escort remained in the Gulf, several other ships of the separate Middle East Task Force operated in the Gulf. The average transit speed of the U.S.S. Nimitz to the South China Sea was less than 20 knots.

5. While we agree that conventionally powered carriers are more dependent on battle group logistics support than nuclear-powered carriers, we do not agree with DOD that fuel consumption concerns limit conventionally powered carriers to the slower speeds of logistics ships. We note that the AOE-class battle group supply ship can sustain speeds of 30 knots and thus will not limit the transit speed of the battle group. In situations where an AOE is not available, the Combat Logistics Force can resupply fuel oil with its worldwide network of prepositioned oilers. Logistics force planners and operators told us they knew of no time when a conventionally powered carrier could not obtain Combat Logistics Force support during peacetime or crisis. Recently, the conventionally powered

carrier U.S.S. Independence (CV-62) traveled from its homeport in Yokosuka, Japan, to the Arabian Gulf at an average speed of 24 knots. During the transit, the ship sustained speeds of at least 27 knots over two-thirds of the time.

6. We added information on more recent carrier deployments to appendix IV.

7. Our report states that the maintenance strategy, along with propulsion type, affects the length of a carrier's employment cycle. Although the Navy's guidance for accomplishing ship depot-level maintenance availabilities nominally sets depot intervals, durations, and mandays by ship class, the Navy has deviated from this guidance for conventionally powered carriers and nuclear-powered cruisers that have been grouped by type for at least the last 8 years. We note that nuclear propulsion maintenance requires exacting and stringent environmental, health, and safety standards. Our analysis shows that, under the Navy's current strategy, nuclear-powered surface ships have longer depot-level maintenance periods than their conventionally powered counterparts. For example, the typical post-deployment maintenance period for a nuclear-powered carrier lasts 6 months and about 62 percent of the work is related to the propulsion plant. The typical post-deployment yard period for a conventionally powered carrier is about 3 months. The nuclear-powered carrier spends more time undergoing propulsion plant work than the conventionally powered carrier does for all its maintenance, repairs, and modernization. A similar relationship exists between conventionally and nuclear-powered surface combatants. Our analysis also shows that a conventionally powered Aegis cruiser or Kidd-class guided-missile destroyer spends about one-fourth the maintenance mandays per deployment as a nuclear-powered cruiser. Furthermore, our analysis shows that a conventionally powered surface combatant spends about 16 percent of its time in depot-level maintenance compared to around 25 percent for a nuclear-powered cruiser. As shown in table VII.1, the nuclear-powered cruiser maintenance cycle is more like a conventionally powered carrier than a conventionally powered cruiser in terms of the time spent in maintenance (about 25 percent) and mandays of work to perform the maintenance (about 38,000 mandays after a typical deployment and over 300,000 mandays for a complex overhaul).

Table VII.1: Maintenance Period Characteristics of Conventionally and Nuclear-Powered Surface Combatants and Aircraft Carriers

Ship type	Cycle time in maintenance (percent)	Typical post-deployment depot maintenance period		Complex overhaul	
		Months	Mandays (thousands)	Months	Mandays (thousands)
Surface combatant					
Conventionally powered	16	2-3	10	8.0	48
Nuclear-powered	24	3-4	38	18.0	350
Aircraft carrier					
Conventionally powered	25	3	45	12.0	376
Nuclear-powered	29	6	162	10.5	289

Source: Our analysis of Navy data.

8. The September 1997 Chief of Naval Operations memorandum stated that to prevent confusion and misunderstanding, the OPNAV Notice 4700² is being revised to reflect these comments. The OPNAV Notice 4700 has not been revised to reflect that information.

9. We included information on the arguments that led to the use of nuclear propulsion for surface ships in the 1960s to provide important historical context for the debate. We did not discuss the arguments that culminated in approval of nuclear propulsion for the Nimitz-class because DOD was unable to provide us with supporting documentation. However, we understand that many of the arguments in favor of nuclear propulsion were the same as those presented in the 1960s.

10. While DOD said that the risk and cost associated with developing the new Aegis capability in parallel with the new design nuclear propulsion plant were factors in its choice of choosing conventional power for Aegis cruisers, it provided no evidence to support this belief. The Secretary of Defense's assessment was that "the military value of an all nuclear-powered Aegis ship program does not warrant the increased costs or, alternatively, the reduced forced levels." DOD was unable to provide support for its rationale for deciding to retire the nuclear-powered surface combatants at an average age of 17 years. Instead, it provided Navy point papers that noted adding the New Threat Upgrade (NTU) will provide extremely capable anti-air warfare for 10 plus years—combat system capabilities comparable to AEGIS ships and an engagement range greater

²Chief of Naval Operations. OPNAV Notice 4700, Subject: Notional Intervals, Durations, Maintenance Cycles, and Repair Mandays for Depot Level Maintenance Availabilities of U.S. Navy Ships.

than AEGIS (until introduction of the Standard Missile (SM2) Block 4 to AEGIS cruisers). The point papers also stated that the nuclear-powered surface combatants are (1) superior to all surface combatants in tactical mobility and (2) the only combatant escorts that do not constrain a CVN battle group's mobility, flexibility, and rapid surge capability—"an essential element of the future force structure."

11. We were asked to assess the cost-effectiveness of conventionally and nuclear-powered carriers and did not perform any comparisons of the advantages and costs of using nuclear power in surface ships versus aircraft carriers.

12. Our congressional mandate was to review the cost-effectiveness of conventionally versus nuclear-powered carriers, not to develop potential designs for a new carrier or to evaluate the cost-effectiveness of such designs. We do not agree that a cost-effectiveness analysis should assume that the next conventionally or nuclear-powered carrier would have the same capabilities and features, nor do we agree that the highest end technology should be assumed in the analysis. Rather, the goal of designing a new carrier is to build a system with the capability necessary to meet U.S. national security objectives. We also note that the Center for Naval Analyses used a methodology similar to ours in some preliminary work it did for the Navy as the Navy began to assess its future carrier needs. This historical perspective covered a wide range of peacetime forward presence, crisis response, and war-fighting scenarios that both types of carriers have faced for over two decades. We believe this provides a sound foundation for evaluating the relative cost and effectiveness of these two ship types.

Although DOD said that the current assessment of a new carrier design would include various features, including new fossil fuel and nuclear-powered designs, we note that in the 1998 Navy Posture Statement, the Secretary of the Navy and the Chief of Naval Operations state, "This next generation nuclear-powered aircraft carrier is scheduled to begin construction in 2006. . ." and "CVX will be the most technologically advanced nuclear-powered carrier the Navy has ever developed."

13. We believe the report adequately addresses the support required for both types of carriers. For example, it specifically states that nuclear-powered carriers can transit long distances faster because, unlike conventionally powered carriers, they do not need to slow for underway

replenishment of propulsion fuel. It also included a table comparing nuclear and conventionally powered carrier transit times that highlights refueling requirements for conventionally powered carriers. We note that DOD's comment that operational commanders task the closest or next-to-deploy carrier rather than selecting a particular carrier is consistent with our finding that the carrier's type of propulsion is not a critical factor in making employment decisions. We also note that the vast majority of Navy ships are fossil fuel-powered, thereby necessitating a continuous logistics presence. In fact, the Navy has specifically designed and strategically located its logistics infrastructure to provide continuous support to peacetime and wartime naval operations. Elements of the logistics infrastructure include naval depots, inventory control points, distribution centers and bases in the United States; advanced overseas support bases located in or near the theater of operations; and a highly mobile fleet of Combat Logistics Force ships that carry a broad range of supplies. Logistics planning to provide that support is a continuous, organized process, performed in parallel with naval operations planning.

A recent example that we believe demonstrates the timeliness and effectiveness of the Navy's worldwide logistics infrastructure was the unanticipated deployment of the conventionally powered U.S.S. Independence from Japan to the Persian Gulf in January 1998, during a confrontation with Iraq, to relieve the U.S.S. Nimitz. On January 21, 1998, the Secretary of Defense ordered the U.S.S. Independence to depart for the Persian Gulf. The carrier got underway on January 23, 1998, and conducted a high-speed transit to the Persian Gulf, arriving on February 5, 1998. During the voyage, the carrier was replenished by three separate Military Sealift Command tankers, already prepositioned in the western Pacific and Indian Ocean areas. Crisis logistics planning enabled the tankers to rendezvous with the carrier to provide needed replenishment without hindering the carrier's ability to respond in a timely manner to fulfill its tasking.

14. Our analysis shows that a conventionally powered carrier steaming at 28 knots would cover 6,740 nautical miles (a distance equivalent to that from Norfolk to the Red Sea) in about 9-1/2 days and arrive with 77 percent of its propulsion fuel remaining. We project that the AOE-6 would still have over 11,700 barrels of DFM remaining to give to other ships. (Our analysis assumed that the AOE-6 had a maximum capacity of 93,600 barrels of DFM. Of this amount, 30,950 barrels would be needed for the

AOE-6's own propulsion, leaving 62,650 barrels available to refuel other ships—the carrier would need 50,893 barrels.)³

Our calculations were based on published fuel consumption rates from the ships' engineering manuals, fuel capacities from ship manuals, and the distances cited in the example. We calculated burn rates based upon the more demanding 28-knot transit vice DOD's 26-knot rate and we assumed that the carrier would be refueled when its DFM levels reached 70 percent of its capacity. Our analysis is very conservative because our burn rates assumed all eight boilers being on-line when only five boilers need to be on-line to sustain a 28-knot speed for the U.S.S. John F. Kennedy (CV-67).

15. Subsequent to providing written comments on our draft report, DOD provided adjusted maintenance data that showed conventionally powered carriers were in depot-level maintenance about 32 percent of the time (26 percent when adjusted for the Service Life Extension Program (SLEP) and the Nimitz-class ships were in depot-level maintenance about 27 percent of the time.

After receiving DOD's comments, we re-examined our methodology but could not replicate DOD's results. Our original results remained—each carrier type spent about 30 percent of its "unadjusted" time from October 1, 1984, to December 31, 1996, in depot-level maintenance availabilities.⁴ We also examined two other time periods to gauge the variability of the results. According to our calculations, from October 1, 1982, through December 31, 1996, conventionally and nuclear-powered carriers were in the shipyards for depot-level maintenance 31 percent and 30 percent of the time, respectively, while accounting for 30 percent of the time for both carrier types from October 1, 1983, through December 31, 1996.

In our draft report, we stated that, after adjusting for the time they spent in SLEP, the conventionally powered carriers collectively would have spent about 23 percent from October 1, 1984, through December 31, 1996, in depot-level maintenance—about 7 percent less than the nuclear-powered carriers. After receiving DOD's comments, we re-examined and modified our methodology for making the SLEP adjustment. According to our revised calculations, the conventionally powered carriers would have spent about

³According to data DOD provided to us on April 2, 1998, Commander Logistics Group Two assumed a 26-knot or higher transit for 10 days, with the transferable propulsion fuel capacity from an AOE-6 class ship (2.1-4.0 million gallons of DFM).

⁴See app. I for a more detailed explanation of our methodology for calculating the availabilities.

24 percent of their time in depot-level maintenance, about 6 percent less than the nuclear-powered carriers. Our adjustments have been incorporated into the report, and our methodology for adjusting SLEP time is discussed in appendix I.

We also examined the effect that refueling overhauls would have on the time that the nuclear-powered carriers would spend in depot-level maintenance. According to current maintenance schedules, starting in mid-1998 and ending in mid-2007, one of the Nimitz-class carriers will be almost continually undergoing a refueling overhaul, a situation analogous to the conventionally powered carrier SLEPs in the 1980s and early 1990s (the notional durations of both a refueling overhaul and a SLEP is 32 months). We found, that from October 1, 1997, through December 31, 2007, the nuclear-powered carriers will spend about 32 percent of their collective time undergoing depot-level maintenance in a shipyard—about 2 percent more than during the original time period. The two operating conventionally powered carriers will spend about 19 percent of their time undergoing depot-level maintenance in a shipyard during this period.

16. We agree that, within the time period we examined, six of nine conventionally powered carriers were inactivated or were within 5 years of inactivation and that these ships would have received less maintenance and modernization. However, because of the timing of the inactivation decision and the actual inactivation, there would have been insufficient time to significantly decrease the amount of maintenance and modernization on the ships prior to their inactivation. For example, the decision to inactivate the Forrestal (CV-59), the Saratoga (CV-60), and the Ranger (CV-61) was first reflected in documents supporting DoD's Fiscal Year 1992 Future Year Defense Plan. The Forrestal and the Ranger were decommissioned in 1993 and the Saratoga was decommissioned in 1994.

These three ships underwent regularly scheduled, and in some cases, extensive maintenance. For example, the Saratoga, underwent a comprehensive 15.9 month overhaul starting in January 1988 that lasted about 1-1/2 months longer than the average overhaul for all conventionally powered carriers. It also underwent SRAs that were longer than average SRAs in 1991 and 1993. Also, the Navy has approved modernization on carriers that are within 5 years of inactivation. For example, as we reported in 1997, the Navy plans to install an improved ship self-defense system on the U.S.S. Kitty Hawk in 2003, 5 years before its inactivation.⁵ According to a carrier maintenance planning official, modernizations

⁵Ship Self Defense: Program Priorities Are Questionable (GAO/NSIAD-97-195R, Aug. 15, 1997).

necessary for safe and effective operation can be and are applied to a carrier within 5 years of its inactivation, and the ship must be maintained so that it can complete its deployments.

We agree that the Kitty Hawk/Kennedy-class carriers were older and may have required more maintenance. Those carriers were, on average, three times as old as the ships of the Nimitz-class, over the actual maintenance periods we examined. Because older ships require more maintenance, the data for the Kitty Hawk/Kennedy-class ships may reflect a lower availability than would the same ships if they were of similar age to the Nimitz-class.

17. Our work shows that nuclear-powered carriers spend more time in maintenance than do conventionally powered carriers. A key reason for the difference is propulsion plant work. According to the Navy's standard maintenance planning factors, a nuclear-powered carrier requires about 613,000 mandays of depot-level maintenance to complete three deployments, about 32 percent more than the 466,000 mandays a conventionally powered carrier requires. A carrier maintenance planning official said propulsion plant maintenance accounts for about 44 percent of the total repair mandays on both conventionally and nuclear-powered carriers. Moreover, according to a Puget Sound Naval Shipyard carrier maintenance report, in a nuclear-powered carrier's predominate post-deployment major maintenance period of 6 months, about 100,000 of the 162,000 notional mandays of work would involve nuclear propulsion plant work. Additionally, a document discussing the factors that must be considered when planning aircraft carrier maintenance ranked propulsion type as the second most important factor, after operational requirements.

18. DOD's assessment of the role maintenance schedules play in a ship's employment cycle relates more to conditions in a crisis situation vice normal peacetime operations. To illustrate, Navy doctrine, as outlined in Naval Warfare Publication 1, Strategic Concepts of the U.S. Navy, states that the length of the employment cycle for each ship class is based on the depot-level maintenance requirements for that class of ship. A regular maintenance program is essential so that operational commanders have ships with the material condition and capabilities to fight and win wars. Furthermore, Navy guidance contained in the Chief of Naval Operation's OPNAV Notice 4700, which provides definitive guidance concerning depot-level maintenance availabilities, states that ships shall accomplish depot maintenance availabilities at the notional intervals, durations, and repair mandays set forth. It also states that the durations specified provide

the best notional estimates for long-range programming. To ensure compatibility with the ship's employment schedule and to facilitate depot work loading, it authorizes minor deviations from the notional depot availability interval.

Commenting on the challenges of providing peacetime presence requirements and the relationship of ship maintenance and deployment schedules, the Commander in Chief, U.S. Pacific Fleet, recently stated,

"The degree of attention required to manage many operational variables—maintenance, training, operating tempo (OPTEMPO), personnel percentage of time in homeport (PERSTEMPO), personnel rotation, new contingencies—is growing, and we are often forced to make tradeoffs...If scheduled maintenance for a ship gets delayed it directly impacts the maintenance, training, or PERSTEMPO of other ships."⁶

The Eisenhower's experience during Desert Shield illustrates the degree of coordination between deployment needs and scheduled maintenance periods. The Eisenhower was not retained in the theater during the initial stages of uncertainty after the 1990 Iraqi invasion of Kuwait, but it returned to Norfolk for a previously scheduled maintenance period.

19. DOD's conclusion that the Navy will maintain a force of 12 carriers is based on an analysis of naval force structure options that it performed during its Quadrennial Defense Review (QDR). Using the Navy's Force Presence Model, DOD analyzed various aircraft carrier force structure options and compared them to the forward presence currently provided in the U.S. European Command, U.S. Central Command, and U.S. Pacific Command areas of responsibility. DOD concluded that a force of 11 active aircraft carriers plus one operational Reserve/training carrier was necessary to satisfy current policy for forward deployed carriers and accommodate real world scheduling constraints.

Our analysis of the comparative number of conventionally and nuclear-powered carriers needed to meet overseas presence requirements was based on the Navy's Force Presence Model, which was also used in the QDR. Specifically, we used standard assumptions relating to carrier type maintenance cycle, average speed of advance, distance, PERSTEMPO restrictions, and length of deployments. We did not postulate what future carrier type maintenance cycles may or may not be in terms of mandays or durations. Although the maintenance strategy for conventionally and

⁶Statement of Admiral Archie Clemens, U.S. Navy, Commander in Chief, U.S. Pacific Fleet, before the Subcommittee on Readiness, House Committee on National Security, Mar. 6, 1998.

nuclear-powered carriers can be similar, the actual maintenance requirements for nuclear-powered carriers are very different than those for conventionally powered carriers. For example, carrier maintenance experts have told us that if an oil-fired steam boiler carrier were moved from its existing maintenance strategy, the EOC to an IMP type cycle, its profile would probably consist of two 4-month PIAs followed by a 8-month DPIA compared to the two 6-month PIAs followed by a 10.5-month DPIA for the nuclear-powered carriers.

20. Our analysis was intended to present a notional comparison of the differences in time between the two carrier types to cover the same distances at the same speeds when factoring in the impact of underway replenishment. We recognize that neither type would sustain high speeds during an entire long-distance voyage. Both types of carriers adjust their speed to control for the proper amount of wind-over-the-deck for air operations; accomplish underway replenishment; conduct propulsion plant drills, and rudder swing checks; and adjust to weather conditions. Nevertheless, both types of carriers can steam at high speeds and have demonstrated this capability for extended periods of time for many consecutive hours and even days.

21. We do not agree with DOD's figures on the amount of propulsion fuel and AOE fuel capacity that would be required for a conventionally powered carrier on a 4,800- and 12,000-nautical mile transit at 28 knots. Based on fuel consumption rates that the Navy provided to us, we found the following.

- A conventionally powered carrier steaming at 28 knots on a 4,800-nautical mile transit would require approximately 1.9 million gallons of replenishment fuel if it were refueled when its propulsion fuel reached 60 percent of its usable capacity. When the AOE fuel requirements (1.4 million gallons) for this voyage are added, a total of 3.3 million gallons of propulsion fuel would be required. This is the equivalent of 0.6 of an AOE based on an AOE's total usable ship propulsion fuel (DFM) capacity of 5.2 million gallons. If the carrier and the AOE were accompanied by a battle group of six fossil-fueled escorts (2 CG-47/52s, 2 DD-963s, and 2 DDG-51s), a total of about 7 million gallons of fuel would be required, the equivalent of 1.3 Sacramento-class ships.
- A conventionally powered carrier on a 12,000-nautical mile transit steaming at 28 knots would require approximately 4.75 million gallons of replenishment fuel if it were refueled when its propulsion fuel reached 60 percent of its usable capacity. When the AOE's fuel requirements

(3.3 million gallons) for this voyage are added to the carrier's, a total of 8 million gallons of propulsion fuel would be required. This is the equivalent of 1.5 AOE ships. If the carrier and the AOE were accompanied by a battle group of six fossil-fueled escorts (2 CG-47/52s, 2 DD-963s, and 2 DDG-51s), a total of about 17.6 million gallons of fuel would be required, the equivalent of 3.4 Sacramento-class ships.

22. We based our transit time and fuel consumption comparisons on the assumption that the conventional carrier would have eight boilers on line for speeds of 28 knots or faster and four boilers for speeds below 28 knots. This produced conservative estimates of transit time and fuel consumption. However, as a Navy-provided document shows, the Kennedy, for example, can maintain a speed of 28 knots with only five boilers on line and 29 knots with six boilers on line, with sufficient steam to operate the catapults in both cases. We believe that such operations over an extended period of time would be more stressful than normal. However, under these conditions, not all boiler rooms would have to be continually manned and operating. Thus, boilers could be rotated off-line for routine preventive or emergent maintenance. Additionally, the boiler maintenance information provided in response to our request that it amplify its comments indicates substantive scheduled maintenance actions are generally only required at quarterly intervals or longer. While the watch-standing requirements would be greater when only four boilers are operating, carriers are supposed to be manned at a sufficient level that their endurance at a peacetime cruising level of readiness is not constrained.⁷

Additionally, Fleet officials familiar with the operation of conventional carriers told us that conventional carriers can operate for extended periods at high speeds. We also noted that they have done so in the past. For example, logs maintained by the Independence during its January/February 1998 transit from Japan to the Arabian Gulf indicated that the ship sailed at 27 knots or faster, generally on six boilers, for over 70 percent of the voyage. The Saratoga, when responding to Iraq's invasion of Kuwait in 1990, sailed at 25 knots or faster for extended intervals again, generally with six boilers on line. As noted elsewhere in this report, this was considered to be the fastest Atlantic Ocean crossing since World War II.

⁷The document discussing the required operating capabilities of the aircraft carriers specifies four readiness conditions for a carrier that is underway. These range from Condition I: Battle Readiness to Condition IV: Peacetime Cruising Readiness. Our review of several extended transits indicates that the carriers generally steam at Condition IV.

23. We agree that conventionally powered carriers normally refuel when their on-board fuel level reaches 50 percent to 60 percent of capacity. However, the 30-percent minimum fuel level we used is consistent with the provisions of various fleet operating instructions and is greater than that allowed in some instances by those instructions. Therefore, we believe that, in a time of crisis, it is reasonable to expect that reaching the intended theater of operations would have priority over maintaining a high fuel level.

24. For a slightly different perspective, compare the crisis response transits of the U.S.S. Nimitz (CVN-68) and the U.S.S. Independence (CV-62) in late 1997 and early 1998 (see app. IV).

25. We added information on more recent carrier deployments to appendix IV, as noted in comment 3. Further, our independent review of Navy records in some cases differed from the facts the Navy provided. For example, the Navy reported that

"In May 1992, EISENHOWER left the Arabian Gulf and transited to the Norwegian Sea steaming 7000 miles at 30 knots average speed. As part of a joint exercise, EISENHOWER sprinted ahead of schedule and launched simulated strikes into northern English air bases earlier than anticipated. The Royal Air Force was taken by complete surprise thinking the battle group was 300-400 miles further south."

Our review showed that in May 1992, the U.S.S. Eisenhower was at its homeport of Norfolk, Virginia, having completed a 6-month deployment on April 2, 1992. Navy records also show that the Eisenhower transited the Strait of Hormuz on February 4, 1992, and proceeded to operate in the North Arabian Sea for 10 days before entering the Gulf of Aden on February 15th. The ship operated in the Red Sea for 4 days, spent 3 days in port in Jeddah, Saudi Arabia, then operated in the Red Sea for another 3 days. The ship transited the Suez Canal on February 27, steamed through the Mediterranean, and spent 5 days in port at Palma de Mallorca, Spain. The Eisenhower passed through the Straits of Gibraltar on March 7th and began operating in the exercise in the Norwegian Sea on March 11. The actual period of time for the Eisenhower to travel from the Arabian Gulf to the Norwegian Sea was approximately 35 days. Had the ship averaged 30 knots, it would have covered 7,000 miles in 10.7 days, including a day to transit the Suez Canal.

The Navy also said that

"On 1 October 1997, NIMITZ was ordered to proceed from the South China Sea (Hong Kong) to the Arabian Gulf at best speed. This 5500 nm transit was completed in 11 days for an average SOA [speed of advance] of about 21 knots. Since NIMITZ was able to conduct flight operations for 6 of the 11 transit days, NIMITZ arrived on station with its airwing fully qualified on 11 October 1997."

Our analysis of this transit indicated that the U.S.S. Nimitz averaged 24 knots for the trip. As discussed earlier, the U.S.S. Independence (CV-62) averaged the same speed when it made a similar voyage about 3 months later. The Nimitz spent 30 percent of the voyage at 30 or more knots (38 percent at 27 knots and above), while its longest sustained period of high-speed sailing was 9 hours.

In another example, the Navy stated that

"In March 1996, the NIMITZ battle group was ordered to move from the Persian Gulf to the western Pacific (Taiwan Straits). The increased self-sustaining capability of a CVN allowed NIMITZ to remain on-station in the Persian Gulf with only one of its (fossil fueled) escorts, while the remaining ships in the battle group began the transit toward east Asian waters. Five days later, NIMITZ departed the Gulf and while en route, refueled her remaining escort and conducted proficiency flight operations prior to overtaking the rest of her battle group as they entered the Taiwan Straits."

Our analysis of this transit indicated that ships of the battle group passed through the Strait of Hormuz approximately 40 hours (1.7 days) before the U.S.S. Nimitz and its escort the U.S.S. Port Royal. The Nimitz averaged 19.8 knots for the transit while spending less than 5 percent of the time at speeds of 27 knots and above. The ship sustained speeds of 28-30 knots one time for a 6.5-hour period.

In another instance, the Navy stated:

"On 23 January 1998, U.S.S. INDEPENDENCE (CV-62) was ordered to transit from Japan to the Arabian Gulf to replace U.S.S. NIMITZ (CVN68), a transit similar to the October 1997 NIMITZ transit. INDEPENDENCE transited 6800 nm with USNS GUADALUPE (TAO 200) at an SOA of about 20 knots, arriving in the Straits of Hormuz on 6 February 1998. INDEPENDENCE did not conduct flight operations en route. Therefore, upon arrival in the Arabian Gulf, INDEPENDENCE required over 3 days of flight operations to qualify her airwing."

Our analysis of Navy transit data showed that the U.S.S. Independence averaged over 24 knots for the entire voyage and spent over 70 percent of

the time at 27 knots and above. During various parts of the transit, the ship sustained 27 or more knots for several lengthy periods of time, including 42, 31, and 27 hours continuous hours. The U.S.S. Independence refueled three times during the voyage from three separate T-AO-187-class oilers. Since these oilers have a top speed of 20 knots, and the Independence steamed at 27 knots most of the time, it is unlikely that any of the oilers remained with the carrier during the entire voyage. Our review of ship logs and other data indicated that Independence aircraft flew during at least 5 days of the transit, with the last period ending after 11:00 p.m. on February 4th, the night before the ship reached the Strait of Hormuz. Our records indicate that the Independence passed through the Strait of Hormuz shortly before noon on February 5, 1998.

26. We agree that the ability to surge is dictated by the scope and complexity of the maintenance to be performed, which varies from availability to availability. In fact, based on discussions with Navy officials directly responsible for maintenance and actual maintenance data, we found that due to the complexity of its maintenance, a nuclear-powered carrier's maintenance period cannot be shortened to the same degree as that of a conventionally powered carrier. The report provides an example for which the data show that a conventionally powered carrier would require less time to surge from maintenance.

We based our analysis on data provided by the Naval Air Force, U.S. Pacific Fleet, and developed by the Navy's aircraft carrier repairs, maintenance, and modernization planning organization. Officials from the Naval Air Force, U. S. Atlantic Fleet reviewed and concurred with the planning organization's information. The data were also provided to the Naval Sea Systems Command's Aircraft Carrier Program Office prior to our receipt. These commands are responsible for coordinating ship maintenance and modernization.

Officials from the planning organization noted that a conventionally powered carrier can be brought out of maintenance before all repairs are completed and begin its transit while remaining repairs and maintenance are performed. The nuclear propulsion plants require a more structured approach because of nuclear maintenance requirements and radiological safety concerns. Atlantic Fleet officials stated it would be easier to surge the conventionally powered carrier because additional workers could easily be assigned to complete the work more quickly by completing work tasks in parallel. In contrast, nuclear-powered carrier work is sequential and there are a finite number of nuclear-certified workers.

27. We did not characterize the Persian Gulf War as the definitive wartime scenario. The report states that the nature of Desert Storm—a major regional conflict—portends the types of conflict in which U.S. forces expect to be engaged in the foreseeable future. This statement is based on our assessment of the QDR, Defense Planning Guidance, and other DOD documents that include regional dangers among the threats facing U.S. forces. For example, the QDR, in discussing the regional dangers confronting the United States, states that Southwest Asia—especially Iraq and Iran—is among the foremost threats of coercion and large-scale, cross border aggression by hostile states with significant military power. Furthermore, according to Defense Planning Guidance,

“The security environment between now and 2015 will also likely be marked by the absence of a ‘global peer competitor’ able to challenge the U.S. militarily around the world as the Soviet Union did during the Cold War. . .the U.S. is the world’s only superpower today, and it is expected to remain so through at least 2015.”

We agree with DOD that the United States benefited from a local supply of oil during the Gulf War. However, based on further analysis, we do not believe this was a controlling factor in the outcome of the Gulf War, nor do we believe it would be a significant factor in any of the threats facing the Nation. The Navy has prepositioned large amounts of fuel oil throughout the Central Command, Indian Ocean, and Western Pacific areas. We used the Gulf War scenario to evaluate the effectiveness of conventionally and nuclear-powered carriers in their war-fighting missions because it actually occurred and involved the most extensive and extended combat use of carrier aviation since the Vietnam conflict.

28. We agree that light wind conditions or the necessity to perform downwind air operations can make sortie generation more difficult. However, our review of carrier transit data indicates that conventionally powered carriers, like nuclear-powered carriers, adjust their steaming speeds to meet operational needs. If conditions and operations call for higher speeds, the propulsion plant in the conventionally powered carriers can quickly generate and sustain higher speeds to support flight operations. Throughout this review, we repeatedly sought examples where conventionally powered carriers were unable to meet operational needs. Navy officials provided no examples.

29. We agree that the Naval Sea Systems Command (NAVSEA) letter states that the nuclear propulsion system gives the nuclear-powered carrier an edge. However, its detailed comparisons noted many similarities between

various aspects of the two carrier types. Additionally, in discussing this analysis with NAVSEA officials, they told us that neither type of carrier possesses any inherent, overriding advantage over the other in its susceptibility to detection or vulnerability. While there are some differences between the two carriers, neither has a distinct advantage that can be specifically attributed to the ship's propulsion type. These statements support our conclusion that the propulsion system does not materially affect survivability. We also note that DOD's response commented on the CVN-71's and later ships' enhanced survivability to antiship cruise missile attack compared to that of CV-67 and the earlier CVN-68 ships. While engine room fires impair a carrier's mobility, analyses we reviewed discussed a carrier's loss in terms of magazine detonation or sinking due to uncontrollable flooding resulting from blast and fragmentation damage. These analyses indicated that the degree and type of magazine protection incorporated into the ship's design is a greater determinant of survivability than is propulsion and showed that the conventionally powered carrier can have a higher probability of surviving an antiship cruise missile attack than can a nuclear-powered carrier. Furthermore, we continue to believe that while refueling does restrict a carrier's ability to maneuver, the need to replenish will be driven as much by the need to replenish other ships of the battle group as by the carrier.

30. We disagree that a new design conventionally powered carrier would necessarily result in a larger and heavier ship, as discussed in comment 1.

31. Increases in fleet oiler requirements because of conventional propulsion in carriers may not be as great as postulated because, in general, infrastructure requirements are seldom increased or decreased in response to small changes in force structure. A 1992 Center For Naval Analyses report on Combat Logistics Force ship requirements for battle forces centered around conventionally or nuclear-powered carriers concluded that nuclear propulsion for carriers alone had only a marginal effect on the number of support ships needed to sustain battle forces in a typical combat scenario. The scenario postulated a naval deployment to a limited regional conflict in Southwest Asia with naval forces supported from bases in the Western Pacific. This scenario was chosen because the extreme distances involved would tend to highlight the differences between the numbers of Combat Logistics Force ships needed to support battle groups with nuclear-powered carriers and battle groups with conventionally powered carriers.

The report also found that on an individual basis, a conventionally powered carrier needs only one-half more of an oiler than a nuclear-powered carrier used in a similar fashion (or, for a force of 12 carriers, an additional 6 fleet oilers). The report noted that earlier studies of Combat Logistics Force requirements used much higher estimates for ship propulsion fuel. This fact may contribute to the view that the nuclear-powered carrier offers a freedom from oilers not possible with conventionally powered carriers. The report also noted that, in practice, carriers, regardless of propulsion type, are replenished whenever operational demands make it possible, typically during rest periods between major flight operations, which normally occur every few days.

As we note in appendix V, the Center for Naval Analyses concluded that the "increased capacity for ordnance and aviation fuel in the CVN [nuclear-powered carrier] design is not sufficient to untether the force from the [logistic] pipeline. The hoped for increase in freedom of operational employment for CVNs is further restricted by the fossil-fuel dependence of the accompanying surface combatants." Another important factor that could affect the ultimate size of the oiler infrastructure is the Navy's general need for a global array of fuel replenishment ships and depots. We note that the Navy requires a worldwide supply system because the ship battle force is mostly a conventionally powered ship force (253 of 349 ships as of April 14, 1998).⁸ Appendix III shows that escort ships of a conventionally powered carrier battle group generally needed from two-thirds to three-quarters of the total battle group's overall underway replenishment fuel requirement.

32. In response to our requests, DOD provided no specific examples where a conventionally powered carrier's inability to accelerate actually caused the situations it mentioned to occur. As stated in the report, ship personnel are aware of wind conditions during flight operations and can adjust the ship's speed, as necessary, to respond to varying landing conditions in a timely manner. Our review of data gathered during specific ship transits revealed numerous examples where dramatic speed and directional changes were made by conventionally powered carriers in short periods of time to respond to operational needs. We identified two instances during the recent high-speed transit of the U.S.S. Independence (CV-62) from Japan to the Persian Gulf where aircraft

⁸The Ship Battle Forces consists of Battle Forces, Mobilization Forces, Category A Assets, Strategic Forces and Support Forces. The Battle Forces include aircraft carriers, surface combatants, submarines, amphibious warfare ships and mine warfare ships in an active status. Combat logistics ships, both active and those under the Military Sealift Command (MSC) and Naval Fleet Auxiliary Force, are also included.

experienced single-engine emergencies. With the exception of a minor speed change in one instance, no other speed or directional changes were made, and both aircraft were recovered safely.

33. Our estimate did not include an allocation of acquisition cost of the fuel delivery costs because we did not have comparable acquisition cost data for facilities (i.e., Department of Energy (DOE) laboratories) that supported the delivery of nuclear power to the Navy's fleet. We view these as sunk costs because they tend to be invariant with the size and mix of the forces. We excluded acquisition costs for all supporting activities and functions whether they supported conventionally or nuclear-powered carriers or both types of carriers.

34. Our pipeline training cost estimate is greater because it includes a more complete universe of costs that are required to provide a steady supply of trained nuclear propulsion plant personnel. In its comments, the Navy estimates training pipeline costs at about \$13.4 million, which is based on an allocation of the \$142 million it spends annually on nuclear training. However, budget data indicate that the Navy spends nearly \$195 million annually for student, instructor, operations, and support personnel and over \$80 million in operations and maintenance funds for its moored ships; the latter amount does not include operations and maintenance funds for classroom training at the Nuclear Power School. Our estimate was based on applying the annual per student training cost, which includes all applicable personnel and operations and maintenance costs, to the estimated annual training requirement to support one nuclear-powered carrier.

35. We allocated the cost of DOE's nuclear support activities based on the benefit received by the nuclear-powered ships. Since the purpose of the Naval Nuclear Propulsion Program is to ensure safe and efficient production of energy, we allocated the program costs according to the amount of energy consumed. This methodology is in accordance with The Federal Accounting Standards Advisory Board (FASAB), which recommends that indirect costs be assigned or allocated based on the consumption or demand for the activity. Moreover, several DOE and Navy officials suggested this was the best allocation methodology. This methodology is also consistent with the way fossil fuel support activities are allocated based on fuel usage. We overstated the costs for nuclear support activities in our draft report, but we adjusted these costs in the final report.

36. Our carrier disposal costs are based on an estimate provided by the Navy in fiscal year 1994 and updated in fiscal year 1996. In its comments, DOD provided a new estimate for the inactivation and disposal costs of a Nimitz-class carrier. We did not use the newer estimate, which was about 40 percent less than the 1996 estimate, because the Navy did not provide any evidence that would support significant changes to the 1996 estimate. Most of the reductions in its new estimate are attributed to a large learning curve and to new technologies.

Officials from the Navy's principal shipyard for nuclear plant inactivation and disposal, the Navy's carrier maintenance experts, and the cost estimating community have told us that it is highly unlikely that any significant cost reductions can be obtained from learning in an episodic activity such as the refueling or inactivations of a Nimitz-class carrier. Large scale activities such as these with intervals of about 4 years do not lend themselves to learning curve reductions on the scale that is included in DOD's new estimate.

Further, over the past 20 years, the methods and technologies have remained fairly constant. The Navy was unable to provide any examples of technologies that could result in potential cost reductions ranging from 20 to 40 percent. Moreover, according to a recent Navy report, "although delaying disposal could potentially allow the development of some new technology to deal with the disposal of radioactivity, there is nothing presently on the horizon that would hold the promise of a more cost effective, environmentally safe disposal method for reactor departments."⁹

37. In our draft report, our estimate for spent nuclear fuel (SNF) was based on a "wet storage" method. The Navy told us that it plans to store SNF using a different method referred to as dry storage. We modified the report accordingly.

⁹Department of the Navy. Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Cruiser, Ohio Class, and Los Angeles Class Naval Reactor Plants (April 1996).

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Related GAO Products

Surface Combatants: Navy Faces Challenges Sustaining Its Current Program (GAO/NSIAD-97-57, May 21, 1997).

Nuclear Waste: Impediments to Completing the Yucca Mountain Repository Project (GAO/RCED-97-30, Jan. 17, 1997).

New Attack Submarine: Program Status (GAO/NSIAD-97-25, Dec. 3, 1996).

Defense Infrastructure: Budget Estimates For 1996-2001 Offer Little Savings for Modernization (GAO/NSIAD-96-131, Apr. 4, 1996).

Marine Corps: Improving Amphibious Capability Would Require Larger Share of Budget Than Previously Provided (GAO/NSIAD-96-47, Feb. 13, 1996).

Future Years Defense Program: 1996 Program Is Considerably Different From the 1995 Program (Letter Report GAO/NSIAD-95-213, Sept. 15, 1995).

Nuclear Carrier Homeporting (GAO/NSIAD-95-146R, Apr. 21, 1995).

Navy's Aircraft Carrier Program: Investment Strategy Options (GAO/NSIAD-95-17, Jan. 1995).

Nuclear Waste: Comprehensive Review of the Disposal Program Is Needed (GAO/RCED-94-299, Sept. 27, 1994).

Nuclear Waste: Foreign Countries Approaches to High-Level Waste Storage and Disposal (GAO/RCED-94-172, Aug. 4, 1994).

Future Years Defense Program: Optimistic Estimates Lead to Billions in Overprogramming (GAO/NSIAD-94-210, July 29, 1994).

Navy Modernization: Alternatives for Achieving a More Affordable Force (GAO/NSIAD-94-171, Apr. 26, 1994).

Navy Carrier Battle Groups: The Structure and Affordability of the Future Force (GAO/NSIAD-93-74, Feb. 25, 1993).

Navy Maintenance: Overseas Ship Repairs and Associated Costs (GAO/NSIAD-93-61, Nov. 13, 1992).

Nuclear Submarines: Navy Efforts to Reduce Inactivation Costs (GAO/NSIAD-92-134, July 21, 1992).

Related GAO Products

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